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AND ABSTRACT OF THE LITERATURE

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Backache Due to Industrial Injuries

The Wet Kata-Thermometer as an Index of the Suitability of Atmospheric Conditions for Heavy Work

Temperature, Humidity, and Air Movement in Industries: The Effective Temperature Index

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BACKACHE DUE TO INDUSTRIAL INJURIES*

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THE study of backache resulting from injuries is of considerable importance to those engaged in the practice of industrial medicine and to the insurance carriers. To orthopedic surgeons, the subject is of special interest because it is timely that they gather and correlate as much information as possible, and that they classify their knowledge and arrive at a unanimity of opinion, so that their judgment as to the etiology, treatment, and general conduct of a case of backache may be expressed with confidence and assurance, and be based on wide experience and thorough analysis. It is furthermore the duty of orthopedic surgeons to teach those interested in industrial surgery what they have acquired in their studies, which have been made deliberately and thoughtfully and with better opportunities than are available, for instance, to the general practitioner, who is often compelled to treat in haste and to pass judgment with insufficient experience and equally meager information.

We have three important questions to answer relative to a case of chronic backache due to an industrial injury. First, has the claimant really a backache? Second, admitting that he has, what is the etiology and what is the pathology responsible for the backache? Third, if there is a competent cause for the backache, how long will the pain and disability last and what disposition of the case with regard to compensation shall we advise?

ESTABLISHING GENUINENESS OF COMPLAINT OF BACKACHE

We may for convenience divide our cases into two groups, those confined to bed and those walking about.

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Bed Ridden Cases

In the first group the problem of differentiating between patients who are telling the truth and those who are malingering is not a very difficult one. Usually in the case of a patient confined to bed because of pain in the back, there is some evident lesion such as a fracture of the spine with cord symptoms, a dislocation with evidences of nerve pressure, a very painful condition such as sciatic scoliosis in which every movement may be very uncomfortable, or some similar manifest and easily recognizable lesion. Furthermore, where there is an actual cause for the pain, the patient is usually anxious to co-operate in the examination. The malingerer, on the other hand, very often attempts to act stupidly, is unwilling to co-operate, complains of pains and discomforts that have no bearing on and no relation to the site of the alleged injury. In these and many other ways the malingerer leads us to suspect that he is fabricating. In the cases confined to bed, close observation of the patient and of the manner and nature of his complaint, coupled with our own judgment of human nature, can be depended on to decide the question as to whether or not the patient is truthful in his statements.

Ambulatory Cases

In the ambulatory cases there are three requisites for a reliable opinion: (1) The patient should be placed in a hospital for observation; (2) he should be under the supervision of a disinterested surgeon; (3) the surgeon should make a slow, deliberate, and sympathetic study. These measures have served me well in the study of cases in which there was some doubt about the nature of the injury, or the veracity of the patient.

Hospitalization.—Hospitalization is desirable for several reasons. These patients are usually sent to surgeons of experience and mature judgment. Probably the surgeon selected is thoroughly occupied during his brief office hour, and, therefore, may not and probably would not have enough time in his office to devote to a slow, systematic investigation of the questions at issue. Furthermore, in the hospital one can have the co-operation of the house officers and the no less important assistance of the nursing staff, both of which groups may be thoroughly trained to inquire into and investigate and observe all of the doubtful situations. If, for instance, one is questioning the ability of the patient to bend his spine, the patient may be on his guard when the physician is examining him, and hold his back so rigidly that it will be impossible for the surgeon to differentiate between alleged and genuine stiffness of the spine. On the other hand, a nurse may, during her rounds in the ward, devise many ways in which to test the truthfulness of the claimant's complaint by suddenly requiring him to stoop for one reason or another. The claimant tested when off his guard is most likely to expose his real self. In addition the claimant who finds himself in a hospital, surrounded by many patients who are really sick and suffering, may be influenced to tell the truth about himself and not to exaggerate his symptoms. Another point in favor of hospitaliza-

tion is that the history in every case can be obtained much more deliberately and thoroughly by a trained intern, who has infinitely less to do than the attending surgeon, than it can be by the surgeon's secretary or by the surgeon himself working under pressure. In this way important details may be discovered and the findings may be more accurately interpreted.

Supervision of a Disinterested Surgeon.—The second requisite in passing judgment in an ambulatory case of chronic backache is that the examination shall be made by a disinterested surgeon. This is of prime importance. We all know that, in instances where a patient with a chronic complaint has been treated unsuccessfully during a period of months or years, there is general embarrassment of the patient and the physician, both of whom welcome a change. When this relationship between doctor and patient has existed for a long time, the judgment of the surgeon is also likely to be warped, and he may not be in a position to think as clearly and decisively as one who sees the claimant afresh. There is a further factor which we are duty bound to face. When the physician is being paid by the insurance carrier he may unconsciously incline his opinion to favor the company. On the other hand, if the surgeon is being paid by the patient, there is the possibility that he may favor the patient by an exaggeration, albeit unconscious and honest, of the patient's difficulties and disability. In either event the true state of affairs may be distorted. When a patient is placed in a hospital under the care of a surgeon who is disinterested, however, as far as the effect of his examination on either the patient or the insurance company is concerned, that surgeon can give an abler and truer opinion than one who is paid by one or the other.

Deliberate and Sympathetic Study of Case.—And now we come to the third requisite in passing judgment in an ambulatory case of chronic disability of the back, namely, a slow, deliberate, and sympathetic study of the history of the case, the findings, and the patient. The chief element in this study is sympathy. We all have seen the type of case under discussion. The patients are usually of foreign birth and cannot accurately communicate to us a clear history of the injury or a consecutive story of the effects of the injury. When a hurried examination is made we are likely to discourage the patient from telling us all that he could and would. On the other hand, if the physician spends plenty of time with his patient and convinces him that he is interested in him, he will gain the patient's confidence, and in return the patient will become confidential with the surgeon, and will, if gently urged on, tell his story in its entirety. Thus the surgeon will be able to obtain, collect, and classify all of the information that appertains to the case and be enabled to pass a proper judgment.

Now let me emphasize what we have been discussing by citing two case histories:

John P. injured his back about two years ago. He was immediately referred by the insurance carrier to its doctor who was a very prominent surgeon. He was given an immediate support and after a number of weeks physiotherapy was instituted and maintained for many months. The diag-

nosis in this case was injury of the back. The hospital history showed that no attempt had been made at a more definite diagnosis; at least no other was recorded. After two years the patient still had backache and disability, but as there was no gross deformity, he was considered a malingerer. He was referred to me by the New York State Department of Labor for an opinion. This patient was taken to a hospital. A careful history showed that he had had immediate pain and disability after his accident and that these symptoms had been present ever since. My examination revealed a hollow in the region of the fourth lumbar vertebra, shallow, to be sure, and easily overlooked, but nevertheless distinct and always present. There was also restriction of all the lumbar motions and marked tenderness over the fourth lumbar. Roentgen ray pictures showed a forward subluxation of the fourth lumbar vertebra (Fig. 1). This man was, of course, no malingerer. The previous examinations had been incompetent.

L. B. complained of pain in the middle of his back, especially when leaning against an object such as the back of a chair. He had sprained his back nine months previously in lifting an object, and it was thought that he had only a sprain and should have already recovered. There had been no external evidence of any other injury, although it was known that he had struck his back against a wall during his accident. X-ray pictures had not been taken, and it was assumed that the patient was exaggerating his symptoms because he looked well, walked without a limp, and held himself in a normal posture. My study showed that he had an ununited fracture of the left transverse process of the first lumbar vertebra, which naturally accounted for his disability.

My findings thus lead me to emphasize that not only must the examination by the surgeon be thorough and inclusive of all parts, but the supplementary investigations by the laboratory assistants must be competent. For instance, a hazy, indistinct X-ray picture may be misleading and may prevent the surgeon from recognizing the cause of the disability.

A careful study of a patient with chronic backache, made in a hospital, by a disinterested surgeon, in a deliberate and sympathetic manner, will certainly yield a large number of positive results in identifying the causes.

Etiology and Pathology of Backache

When we have determined that the patient really has a chronic backache, we must investigate its etiology and pathology. This study may be facilitated by a division of the cases into two groups, those due to a bone lesion and those due to a lesion of the soft tissue. This study is not an exhaustive one, but is merely an attempt at a practical classification of those types of backache, and of those lesions causing backache, which ordinarily come under our supervision.

Backache Due to Bone Lesion

Under the division of backache due to a bone lesion we have the following causes:

1. Fracture of a vertebra.
   a. Body.
   b. Processes.
2. Fracture of scapula.
3. Fracture of ribs.
4. Fracture of pelvis.
5. Congenital vertebral malformation.
   a. Asymmetry of body or processes.
   b. Spina bifida occulta.
   c. Supernumerary vertebrae.
   d. Missing vertebrae.

   Congenital lesions of ribs.
6. Spondylolisthesis.
7. Lateral dislocation of a vertebra.
8. Dislocation of sacro-iliac joints.
9. Arthritis of spine.

Fracture of a Vertebra.—In a fracture of the body of a vertebra diagnosis is facilitated by a history of an injury which caused a sudden forced flexion of the body, as in receiving a blow on the back while bent forward. The pain is distinctly localized at the site of the injury. There is localized tenderness, and there may be an angular deformity of the spine. The X-ray pictures, if properly taken, are definitely indicative of the location and extent of the fracture. The presence of motor and sensory changes will aid

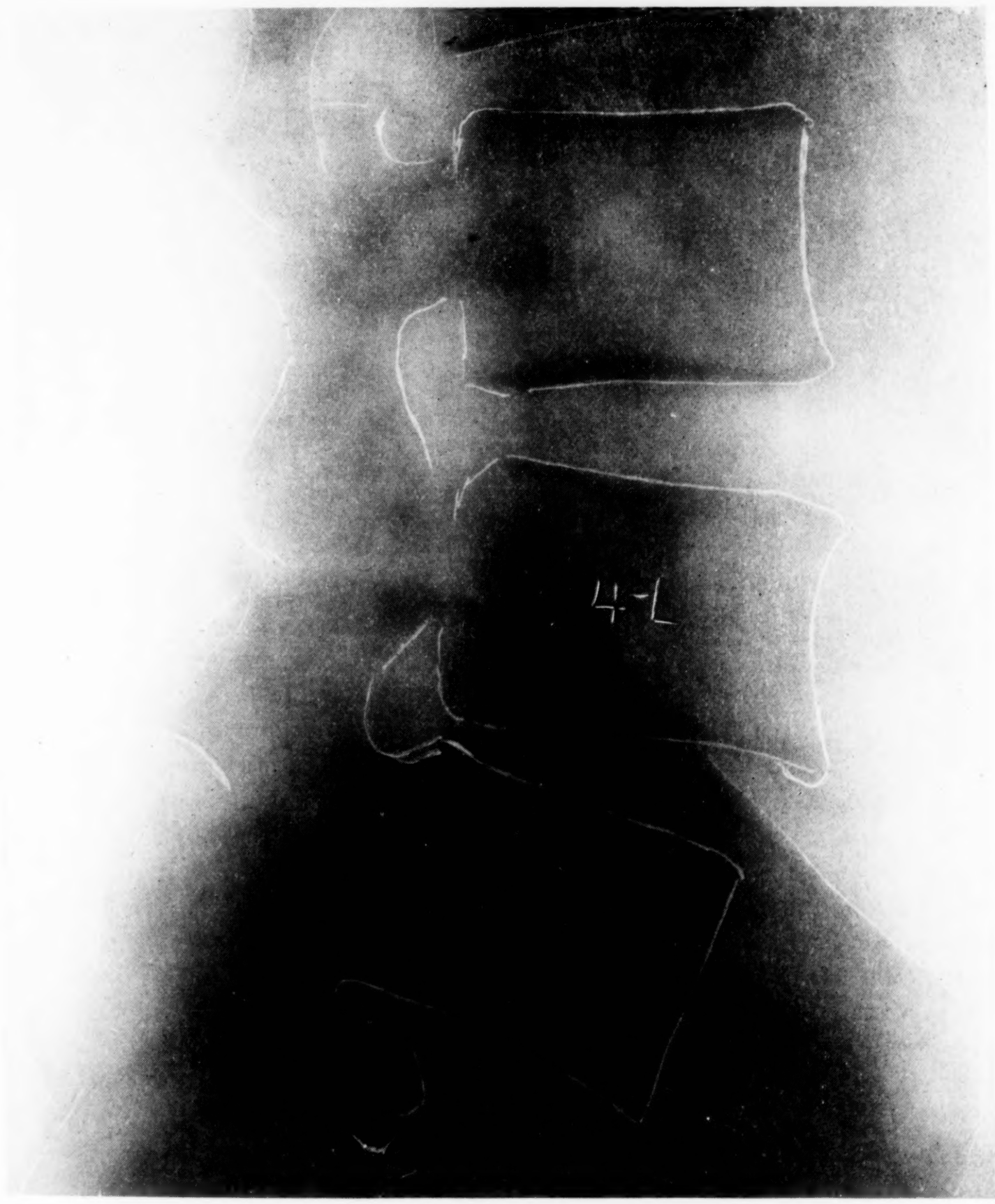

FIG. 1.—Lateral view of the lumbar spine showing forward subluxation of the fourth lumbar vertebra. The outlines of the vertebrae have been purposely emphasized.

in the differential diagnosis, which is easily made if the examination is thorough and competent.

A fracture of a transverse process usually results from a direct blow on the back. I do not recall a single instance in which there was not a distinct history of a direct trauma, though conceivably a fracture may result from a strong muscular force.

A fracture of a spinous process is always the result of a direct injury. It may occur as an isolated lesion, but usually it is part of a very extensive injury to a vertebra. Its absolute diagnosis is possible only by a positive lateral roentgenogram.

Fractures of the laminae or pedicles are found only as part of a more extensive injury, such as fracture of a vertebral body, spondylolisthesis, or lateral displacement of a vertebra. I have never seen a case in which there was an undoubted, isolated fracture of a lamina or of a vertebral pedicle. The commonest lesion of this group is a fracture of a transverse process. Several processes, usually on the same side, may be broken (Fig. 2). The fragments may be in contact or widely separated. The symptoms vary from being mild and inconsequential to being very severe, continuous, and disabling.

Several years ago I examined an industrial case in which there was no complaint referable to the back, but I found a distinct fracture of a lumbar vertebra. On the other hand, and this is very important to keep in mind, in many instances the disability may persist for many months. In the susceptible individual, aware of the diagnosis, the symptoms may be prolonged. Usually there is greater discomfort in those cases with separation of the fragments than in those where there is no hiatus. These fractures occur frequently and are found usually in the lumbar region. They occur in the cervical and dorsal spine only as a complication of a fracture of the body or of a dislocation. I have never seen an isolated fracture of a dorsal transverse process. The healing takes place very slowly and never by an abundant callus. Nonunion is not infrequent. When disability and discomfort have persisted for a long time, I deem it advisable to remove the outer fragment.

Fracture of Scapula.—A fracture of the scapula occurs either through the neck or through the body of this bone (Fig. 3). There is a history of a direct blow on the shoulder, on the scapula, or on the arm, or of a severe wrenching of the arm. The fracture is linear and may be single or multiple. In a fracture of the body there is usually slight displacement or none at all. In fractures of the neck of the scapula there may be some vertical displacement of the glenoid process. The diagnosis is difficult because the symptoms usually simulate those of a shoulder injury and do not direct one's attention to the scapula; the X-ray pictures are usually indistinct. The patient complains of pain in either the shoulder or the upper part of the back, and of difficulty in moving the shoulder. Careful examination will reveal localized tenderness of the body of the scapula or tenderness in the axilla in the case of a fracture of the neck. The diagnosis is made certain only by a positive X-ray picture. As the X-ray tube is centered over the shoulder in cases of this type, one must

examine the films rather carefully, otherwise a linear defect in the scapula will be overlooked. No special treatment is necessary beyond moderate immobilization of the arm against the chest. The prognosis is good, as the healing occurs rapidly and leaves practically no disability. In one instance of fracture of the neck of the scapula in an old man, stiffness of the shoulder lasted over a year.

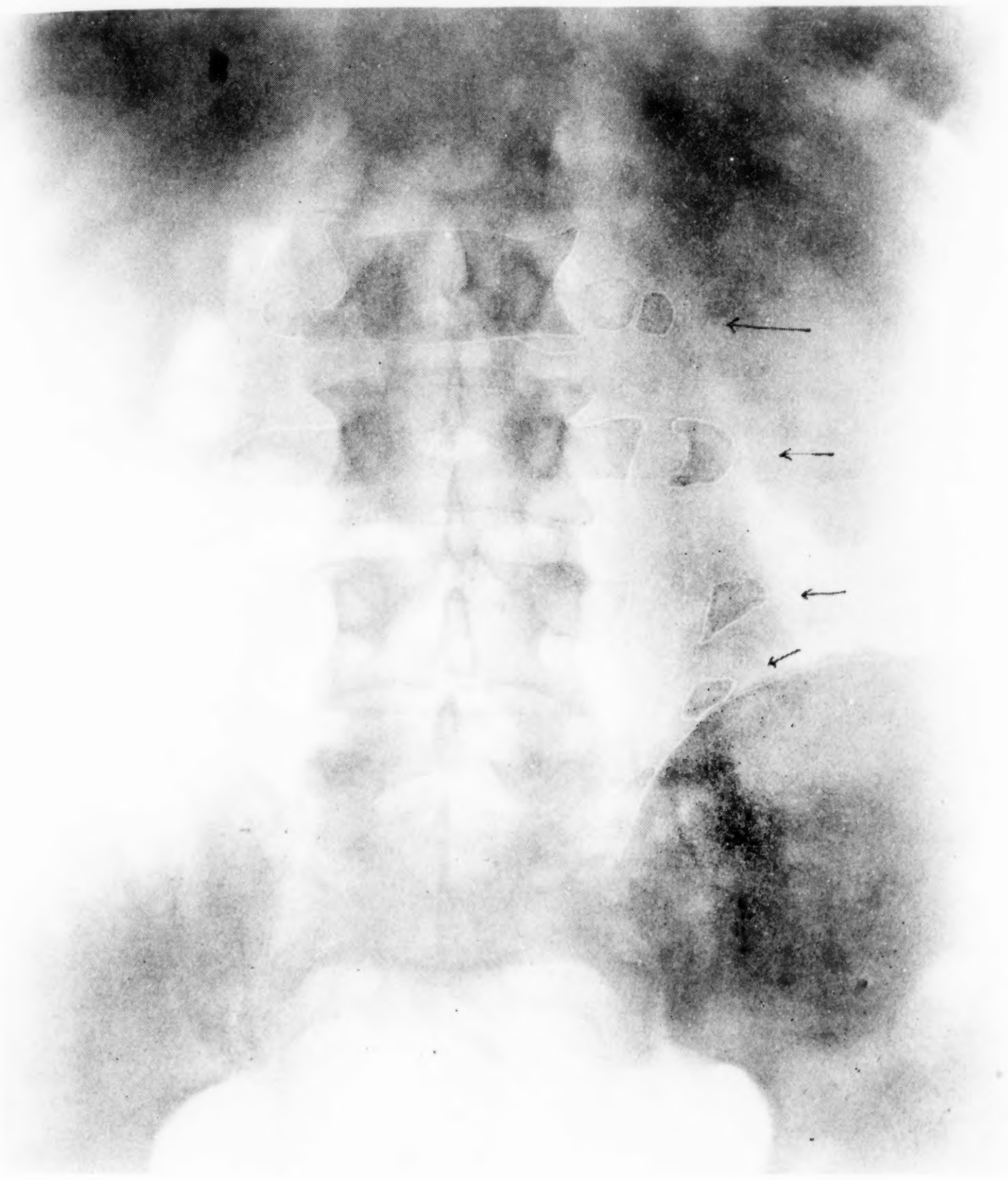

FIG. 2.—Fracture of the left transverse processes of the second, third, fourth, and fifth lumbar vertebrae with increasing separation of the fragments from the second to the last lumbar vertebrae. The arrows point to the outer fragments. The outlines of the fragments have been purposely emphasized.

Fracture of Ribs.—This lesion often causes backache when the break is through the vertebral extremity. Usu-

ally there is localized pain and tenderness, and the X-ray picture shows a break in the rib with moderate or little vertical displacement of the fragments. In the exceptional case there may be an interval between the fragments. In industrial injuries it is common to see several ribs broken. The symptoms may be severe for a few days and then rapidly subside, usually disappearing entirely in about a month. Exceptionally, there may be disabling pain and tenderness for several months. This does not de-

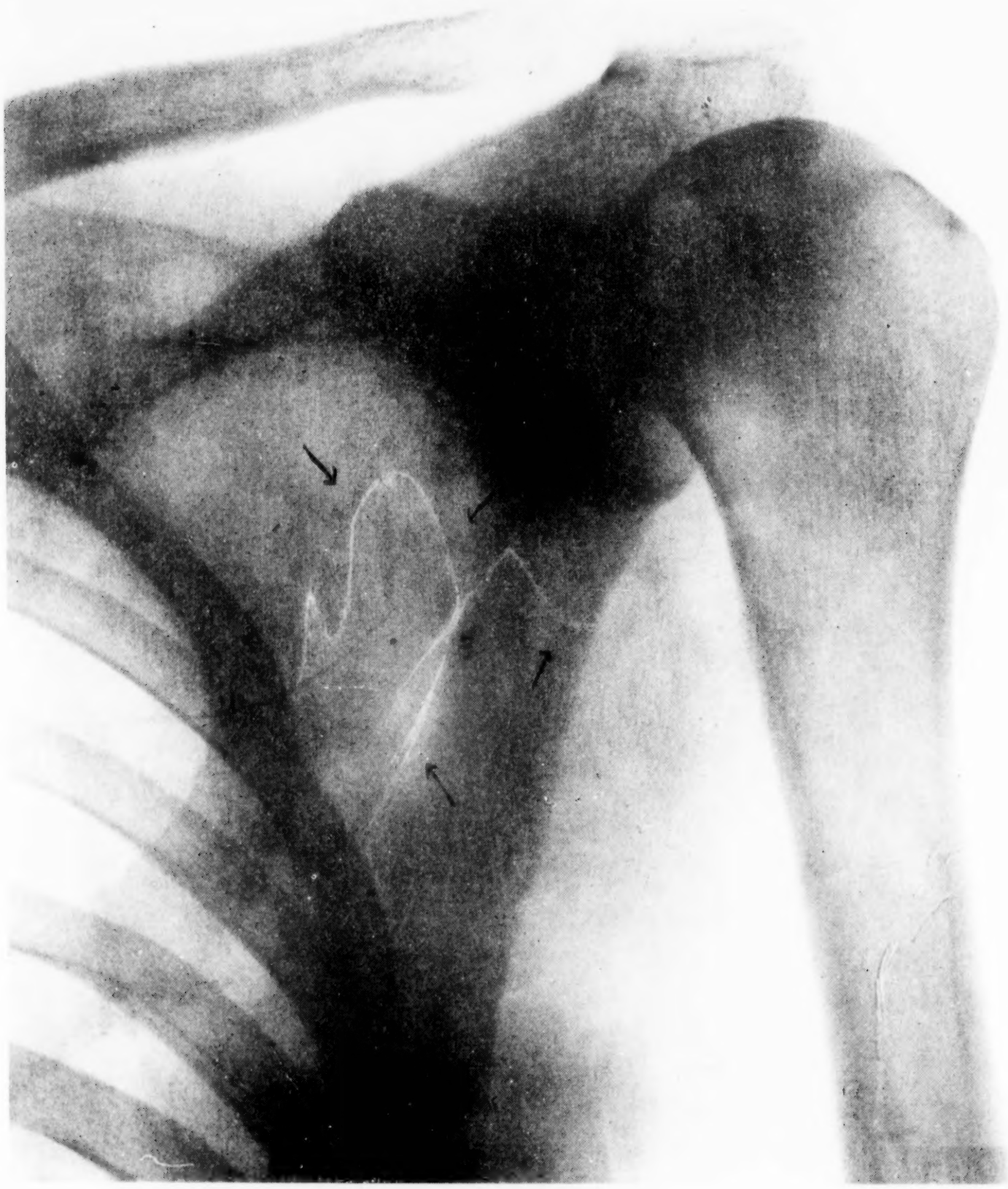

FIG. 3.—Showing multiple fissure fractures of the body of the scapula. The film was retouched so that the fracture lines would show in the print. In the original film the fracture lines appear irregular and ragged. The arrows point to the lines of fracture.

pend on the severity of the lesion and may be found in a linear fracture which appears healed; it is probably due to pressure of the callus upon the intercostal nerves.

FIG. 4.—X-ray picture of the pelvis of an old man who was in an automobile accident. On one side of the pelvis it will be seen that there are two fractures of the ascending ramus of the pubic bone and a fracture of the descending ramus at its junction with the ischium. On the other side there is a fracture of the descending ramus of the pubic bone at its junction with the ischium and a fracture of the ascending ramus which has been displaced downward very markedly.

Fracture of Pelvis.—Fracture of the pelvis occurs frequently among industrial accidents. Sometimes only one of the pelvic bones may be broken or several of the bones may be fractured simultaneously (Fig. 4). Not infrequently the bones on both sides are broken, with resultant deformity of the pelvis. In the order of frequency the fractures occur in the os pubis, in the ischium, and in

the ilium. The exact mechanism of the fracture is difficult to determine, but one usually obtains a history of a direct blow. The multiple fractures occur in a crushing injury. The fracture may be linear or comminuted. The entire substance of the bone is involved, with displacement of the fragments resulting in a change in the shape and size of one or both sides of the pelvis. Occasionally one sees a case of partial fracture or linear infraction of the ischium. If the pubis or ischium is broken, the obturator foramen is reduced in size and altered in shape. In a fracture of the ilium, the fracture line is most often antero-posterior and there is rarely any displacement or alteration of the pelvic form. In the very severe injuries there may be damage to the pelvic or urinary organs, or severe sprain or even fracture dislocation of one or both sacro-iliac joints. In the latter case there may be marked rotation of the affected os innominatum (Fig. 5).

FIG. 5.—This patient, a vigorous young man, was injured by falling on his left side. Stereoscopic X-ray pictures of the pelvis were taken. This picture is a print of one of the stereoscopic films and shows definite upward displacement of the left ilium, an increase in the joint space of the upper portion of the left sacro-iliac joint and rotation of the left os innominatum, as indicated by the fact that its width, as seen in the X-ray picture, is narrower than that on the opposite side. The arrows are on the side of the injury. The upper one points to the increase in the joint space; the lower one points to the upward displacement of the ilium.

The symptoms in the uncomplicated case are rather mild. In some the

pain is so slight that the patient does not take to bed; the fracture heals and is discovered only accidentally months after its occurrence. Usually there is moderate pain in the region of the break. In the first fortnight there may be localized swelling and discoloration. There is always localized tenderness which tends to last for many months. I have seen cases in which there was tenderness six and nine months after the injury; the X-ray pictures showed that the fracture was healed and there was only a small amount of callus. Evidently the healing goes on very slowly. The disability lasts for at least several months even in a simple fracture. In fractures of the ilium there is moderate, low backache. In those cases in which there is associated injury to the sacro-iliac joints, the backache is severe and may be disabling. In the first few weeks of a fracture of any part of the pelvis there is usually moderate restriction of the spinal motions and resultant disability because the motions in the back cause movement at the site of fracture.

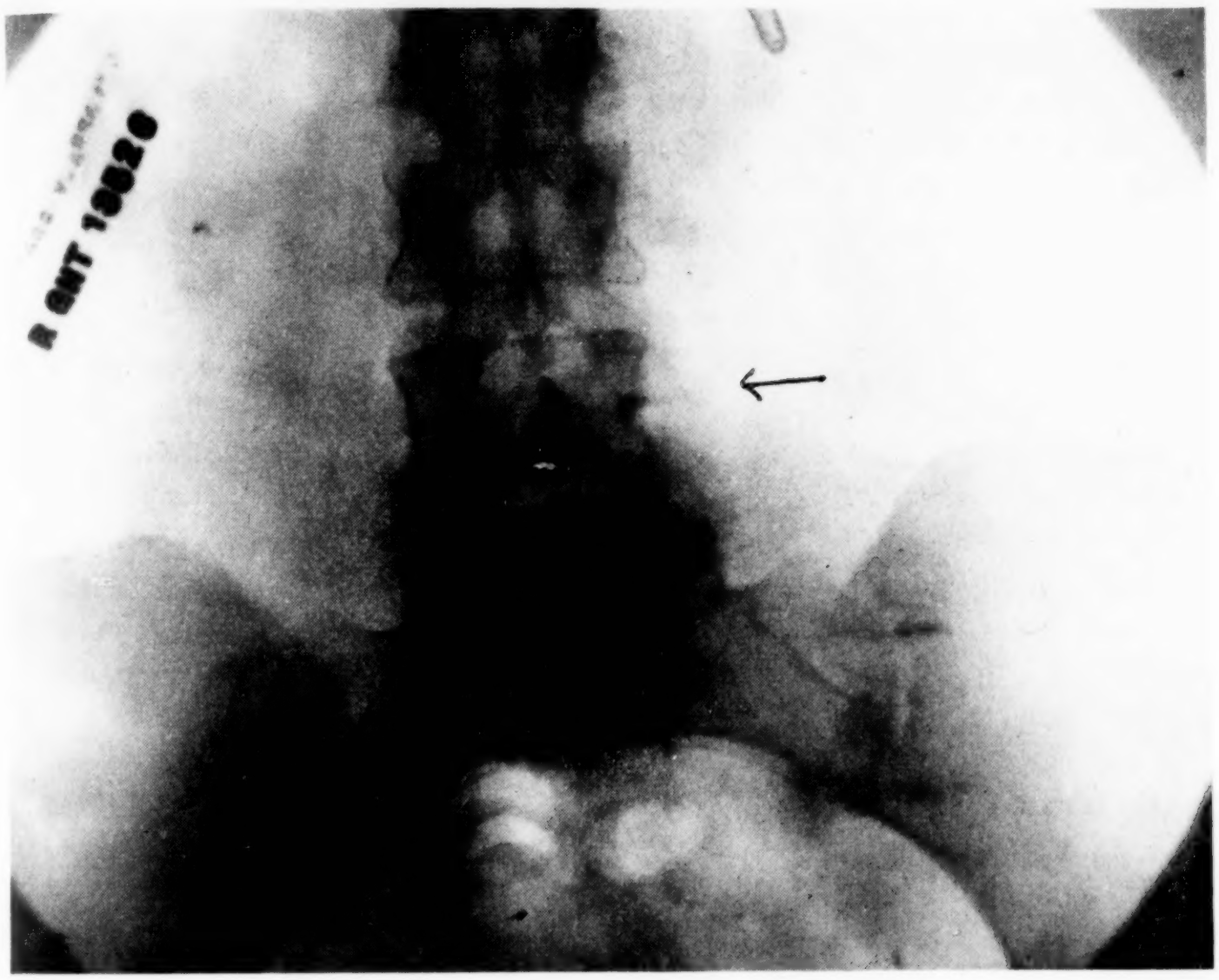

FIG. 6.—This picture is that of the lumbar spine of a woman who fell on her back. In this fall she twisted her spine. There is lateral displacement of the fourth lumbar vertebra.

The treatment depends chiefly on the associated lesions. If there is a lesion of the pelvic or urinary tissues, it demands immediate attention. For the fracture, nothing helps but rest and moderate immobilization by means of a circular flannel or plaster of

Paris bandage, or perhaps a single or double spica bandage. Walking may be permitted two to four weeks after the injury. No attempt at improvement of the position of the fragments is necessary or advisable. In several cases of recent comminuted fracture of the pelvis in females, I attempted by gentle vaginal manipulation to reduce the displaced fragments, but never succeeded. In one case of fracture of the os pubis with moderate displacement, the attending physician insisted, against my advice, on attempting to improve the alignment by forced abduction of the leg on the same side, under an anesthetic. The result was disastrous because the displacement was increased and the patient suffered great pain for many months.

The prognosis in uncomplicated fracture of one or more of the bones of the pelvis is good. With conservative treatment the fracture heals and the patient has rarely more than temporary disability. In cases with marked deformity there may be permanent disability. If a contracted pelvis has resulted, in a female, we must anticipate difficulty in childbirth. When great lateral distortion of the pelvis has occurred, as in cases of fracture of the pelvis with dislocation of one or both sacro-iliac joints, a limp and difficulty in walking may result. Recently in a case with a simple fracture of the os pubis, which I treated, there occurred a complicating subperitoneal hemorrhage with infection, and, fortunately, spontaneous rupture of the abscess into the rectum with complete recovery.

Congenital Malformations and Lesions.—Spina bifida occulta, hemivertebra, an extra or missing vertebra, absent ribs, fused ribs, fused vertebrae, and enlarged vertebral transverse processes may predispose to traumatic lesions giving backache, but by themselves they do not cause symptoms. This view is accepted by all physicians except in relation to large transverse processes in the fourth and fifth lumbar vertebrae. Some believe that a transverse process on the fifth lumbar large enough to be in contact with the ilium in certain positions of the body, or long enough to cause continuous friction, causes backache and sciatic pain. This may be true occasionally, but the mere presence of an abnormal process is not sufficient to account for backache unless there is a definite and consistent relation between the anatomic anomaly and the symptoms. It is the experience of many of us that we often discover the presence of abnormally large transverse processes, simple or bifid, in contact with or connected by a joint with the ilium, which do not give any symptoms. In rare instances localized pain and tenderness over an unusually large process may warrant advising its removal. We must recall, however, that the process has been present for many years prior to the symptoms which are probably due to an injury of the adjacent tissues. Furthermore, removal of the last lumbar transverse process is a difficult operation and unfortunately is not always followed by the anticipated relief of the pain.

A good X-ray picture is indispensable to the diagnosis of a lesion of a transverse process. It is well also, unless the picture is absolutely pathognomonic, not to rely on one view or one film. For instance, in the case of a congenitally small transverse lum-

bar process and an adjacent fecalith, the appearance may simulate a fracture of a normal transverse process. Several views will explain the simulation. It is well to emphasize that in a case of fracture the adjacent surfaces of the broken process are irregular and not smooth. In the case of a large transverse process, one view may show the process in intimate contact with the ilium, while a second view taken at a different angle may show a wide interval between the bones.

Spondylolisthesis.—The symptoms of backache—stiffness and tenderness of the back—are indicative of an injury to the back. If there is a distinct hollow above the sacrum, it is very significant of a forward slipping of a vertebra. It is not a pathognomonic finding, because in persons with marked lordosis, especially in stout women, there is often seen a marked depression above the sacrum. However, at times it may be so marked and so limited to the area just above the sacrum, that it is a reliable sign of dislocation. The X-ray picture, as I have pointed out several times, is pathognomonic. In the anteroposterior view there is seen an outline of the superior surface of the dislocated vertebra beneath a column of quadrilateral shadows. In the lateral view, of course, the anteroposterior displacement makes the diagnosis self-evident.

Some surgeons have questioned whether this lesion is ever traumatic, stating that it is a congenital defect and cannot result from an injury. I have seen several cases in which the characteristic picture was found following a severe muscular effort whereas prior thereto there was no discomfort or deformity at the lumbosacral junction. It may be entirely true that in some persons there is a congenital defect in and about the lumbosacral area which predisposes to spondylolisthesis, but I am certain that in a large percentage of the cases, particularly in men, the lesion is brought on by a trauma, which is usually caused by muscular effort.

The best treatment, I believe, is a fusion operation using a bone graft. Conservative treatment employing prolonged rest and immobilization may suffice, and I have seen several patients progress fairly well under such care. Theoretically, however, it appears more reasonable to ankylose a spinal area which has weak ligamentous structures. Attempt at reduction of the dislocation, in our present state of information of the physiology and mechanism of the spine, is unwarranted. The proposed manipulations are crude and unscientific, and do not accurately deliver a reducing force. In the only case in which I attempted reduction by manipulation, I was unsuccessful and the patient suffered much discomfort for several days.

Lateral Dislocation of a Vertebra.—This lesion may be pathologic, secondary to a disease such as tuberculosis or syphilis, and as such it is seen commonly. It has no special significance, and is recognized only by the X-ray examination, giving no characteristic clinical symptoms. It may be traumatic (Fig. 6). It is not infrequently seen complicating an extensive fracture of the spine. As an isolated traumatic lesion without an accompanying fracture it is very rare. It causes the usual symptoms of a trau matic lesion of the back—namely,

backache, stiffness, limitation of spinal motions, and disability. The diagnosis can be made only by an X-ray examination. The lesion is apparently caused by a direct blow in which the body is twisted laterally.

Dislocation of Sacro-Iliac Joints.—This lesion occurs rarely, and only as the result of a very severe injury either during parturition or when there are multiple fractures of the pelvis. The evidence of the dislocation is so clear that it is unmistakable. The symptoms in a traumatic case are referable to the affected sacro-iliac joints. Usually they are not very marked in the early stages or they are overshadowed by the severity of the symptoms of the associated conditions. In the later stages there may be very little discomfort and slight disability, or there may be marked backache and difficulty in walking. The pain is only exceptionally intense. I have seen several cases of dislocation of the sacro-iliac joints and multiple fractures of the pelvis in which healing progressed favorably; though the pelvis was greatly distorted by the fracture dislocation and the callus formation, there were very few symptoms. When the symptoms are pronounced, as in the occasional traumatic case and commonly in the obstetric cases, an arthrodesis is advisable.

Minor degrees of dislocation or subluxation cannot be diagnosed with any measure of accuracy and cannot be demonstrated with certainty by any of the ordinary clinical methods, although it must be admitted that the lesion is theoretically possible. Some roentgenologists use the term rather loosely, and without competent reasons refer to instances of slight apparent increase in the intra-articular joint space as cases of dislocation of the sacro-iliac joints. I have seen many cases in which the joint space on one side was greater than that on the other, but there were no symptoms referable to it nor was there a history of any injury. A much more debatable finding is that in which the inferior borders of the adjacent articular surfaces of the ilium and sacrum are not on the same horizontal level, but are separated a quarter of an inch or thereabout. If such a finding is present in the face of a history of an injury, and the symptoms of pain and tenderness are referred to that locality, it may be permissible to believe the condition to be one of traumatic partial dislocation or laxity of the joint (see Fig. 5). I have met with two or three such cases. I hasten to add, however, that I have seen several instances with apparent vertical displacement in the sacro-iliac joint, but with no history of trauma and no symptoms referable to it, indicating that the finding may be an anomaly.

Arthritis of Spine.—It has long been a debated subject as to whether an injury can cause an inflammation of the spine. Some physicians have even denied that injury can aggravate an existing spondylitis. My experience leads me to answer both questions in the affirmative. I have seen many patients with osteo-arthritis of the spine who were apparently perfectly well up to the time of the injury; at least it is certain that they had been able to do their usual work which, in some instances, required much bending. From this information it is necessary to conclude that the patients had had no pain, and that the spines had

been mobile. Following the injury, pain, disability, and stiffness appeared. Often the backache lasts for years and completely disables the patient. In this type of case in which many marginal osteophytes and the usual symptoms of osteo-arthritis are seen, one would not say that the osteo-arthritis had been caused by the injury, for many of the osteophytes antedate the alleged accident, but the injury evidently caused damage to the adjacent soft parts or stirred up and aggravated a latent inflammation, thus bringing about a disability which is traumatic in origin and compensable.

Nobody today doubts the fact that an injury applied to an inflamed knee or ankle, be it tuberculous, syphilitic, infectious, or of some other variety, would cause an aggravation of that inflammation. It has also been definitely proved that an injury to a joint like the knee or the hip may be directly responsible for a tuberculous invasion. In the same manner the spine may be the seat of a *locus minoris resistentiae*, and through an injury it may be made susceptible to a hematogenic infection. I have seen definite instances in which the patient was perfectly well prior to the accident which initiated a distinct inflammation of the vertebral joints. For example the following cases are cited:

Evelyn C., 40 years old, was well before her injury. She was able to walk, dance, and work regularly. She fell and struck her back. At first she had pain in her back and moderate stiffness and it was thought that she had a simple contusion. Some months later the symptoms persisted, stiffness appeared, and the X-ray showed haziness of the vertebrae. A spinal fusion was advised, and at operation it was found that the articular and spinous processes were soft and evidently diseased. This was unquestionably a case of traumatic spondylitis.

Pasquale C., 36 years old, was referred to me by the New York State Department of Labor. He was well until two years before, when he fell off a ladder and struck his back. He had immediate backache and disability, both of which persisted. Examination showed marked muscle spasm and restriction of the spinal motions. The X-ray pictures showed rarefaction of the borders and haziness of the articular processes and facets of the lumbar vertebrae. He evidently had a traumatic spondylitis.

Backache Due to Lesion of Soft Tissues

Backache may also be the result of a lesion of the soft tissues such as the following:

1. Derangement of sacro-iliac joint.
2. Sprain of vertebral joints.
3. Strain of muscles of back.
4. Gluteal myositis.
5. Sciatic scoliosis.

Derangement of Sacro-Iliac Joint.—This is a clinical entity the picture of which is familiar to all of us. I would define it as a lesion resulting from a severe or sudden muscular effort such as lifting a rock, pushing a wheelbarrow, hauling a heavy load, or rising suddenly from the stooped position. The patient complains of pain over the sacro-iliac area which is moderately tender. The motions of the back are restricted and the patient has a variable degree of disability. There may be associated symptoms such as pain in the sacro-iliac joint on lateral compression of the pelvis, on upward pressure on the ischium, or on straight leg raising on the same or on the opposite side. The X-ray picture is negative. It is impossible to give an exact account of the pathol-

ogy, for no acute cases have come to autopsy and very few to immediate operation. In all probability there is an acute sprain of the joint with synovitis and some injury to the sacro-iliac ligaments. If the symptoms persist, a definite arthritis may ensue. This has been proved by Dr. Smith-Peterson.

The symptoms, whether mild or severe, may be temporary and disappear completely. In some persons the condition recurs frequently and may become chronic. The symptoms may persist following the initial attack and, because they are chiefly subjective, difficulty may arise in explaining and justifying prolonged disability. Our experience, however, is sufficiently broad in both industrial and civil accidents to warrant the assertion that acute traumatic derangement of the sacro-iliac joint may persist and cause prolonged disability. In a compensation case, when one is assured that the claimant is not malingering, localized pain and tenderness over a sacro-iliac joint and persistent disability are sufficient to establish the diagnosis of derangement of the sacro-iliac joint.

Sprain of Vertebral Joints.—As a result of muscular effort there frequently occurs a sprain of the lumbar joints, most often of the lumbosacral joint. From an anatomic arrangement of the sacrum and last lumbar vertebra, the latter tends to slip off the sacrum, and the ligaments and muscles are continuously under severe tension and are easily injured. Clinically one frequently sees persons who, in rising from the stooped position, experience a sharp pain in the lumbosacral area. This joint becomes very tender and the motions of the lumbar spine are partially restricted. The symptoms, while at times severe, are usually of short duration.

Occasionally we see also sprains of the other vertebral or the costovertebral joints. In the dorsal region this lesion is very infrequent because of the ample protection through the skeleton of the thorax, the numerous muscles, the many short ligaments, and the small range of motion in this segment of the spine.

Strain of Muscles of Back.—The muscles of the back may be injured through sudden or prolonged effort or through direct injury as in a contusion. Usually there is local pain and tenderness leading to disability on effort. The symptoms are temporary and rarely disabling for more than a short period. In exceptional instances the backache persists for several months, as in the following cases:

Walter H., aged 50, strained his back in lifting a heavy weight of iron several months before I saw him. He complained of continuous backache. The X-ray picture was negative, but there was marked tenderness of the lumbar muscles. He had a chronic strain, perhaps a myositis, of the lumbar muscles.

James M. injured his back in a fall seven months previous to the time I saw him. He had sustained a fracture of several ribs which had already healed. He had persistent though moderate pain in his back, however, and definite tenderness of the dorsal and lumbar muscles, indicative of a chronic strain or myositis of his spinal muscles.

Gluteal Myositis.—This lesion is of rare occurrence. It is usually found after a violent effort in which the gluteal muscles undergo unaccustomed

strain, or in a fall in which there is severe wrenching or direct injury of the gluteal tissues. The patient complains of pain and marked tenderness in the buttock; he has difficulty in walking or lying prone or supine. Sitting or lying on the unaffected side, with the hip on the painful side flexed, is the most comfortable position. The gluteus medius is more often involved than are the other gluteals. The diagnosis is based on the clinical picture alone, as there is as yet no histologic evidence. The symptoms tend to persist for weeks and months and are usually relieved by physiotherapy. In the more resistant cases it is advisable to operate and strip the gluteals from the ilium.

Sciatic Scoliosis.—This is a painful condition of the back and one lower limb in which the trunk is persistently bent forward and to one side. It is not a disease entity but a symptom resulting from a lesion of the lumbar back, of the sacro-iliac joints, from gluteal myositis, or from sciatica. The deformity is so conspicuous that the diagnosis is never questioned. The important point is to decide the exact location of the lesion and the pathology which will determine the course of treatment.

Consideration of Disability and Compensation

When we have determined that the claimant has a backache due to a competent producing cause, and when we have discovered the location of the lesion and its exact pathology and have instituted appropriate treatment, we have a third question to answer in relation to compensation for such cases. The prognosis looms up as a very important phase of our considerations and brings up the questions as to how long the symptoms will last and what the ultimate functional result will be, and what disposition should be made of the case. These queries cannot be answered briefly, and in every case involve a study of numerous factors, some of which I shall now discuss.

Duration of Symptoms and Disability

The symptoms and the disability may be prolonged for many reasons. First, the lesion may be a severe one and require months or years for a proper healing. We may confidently expect a simple fracture of a rib to be well in six to eight weeks; a sciatic scoliosis may be cured in six months; but a fractured spine will take a minimum of one year and usually much longer before the claimant can do any work, and if his job involves laborious duties he may never be able to return to it.

Second, there may be a preexisting lesion which has been aggravated by the recent injury and which causes a prolonged illness and partial or permanent disability. I would like again to refer to a familiar occurrence. A patient with a quiescent osteo-arthritis of the spine suffers a strain of the back by lifting an unusually heavy load. Under ordinary conditions we expect a man having a strain of the spinal muscles or ligaments to be well in a few weeks. In the example chosen, however, the backache and disability persist and there is increasing stiffness of the spine. This may continue to complete or nearly complete anky-

losis of the spine with a high percentage of functional disturbance. The X-ray pictures show an advanced degree of osteo-arthritis which was evidently activated and aggravated by the simple injury of strain of the back. It is well also that we recognize and acknowledge the fact that in laborers healing often takes place more slowly than in the nonlaboring class. I am now referring particularly to those who are engaged in strenuous physical labor and not to the white collar employees. This apparently does not apply to open wounds but to "closed injuries" like sprains, contusions, wrenching of joints, and so forth. I have seen simple sprains of the wrist and ankle which ought to be well in two weeks last for many months, and an uncomplicated sprain of the lumbosacral joint cause disability for several years. I do not know of any convincing explanation of this fact.

Third, the symptoms and the disability in a compensation case may be prolonged as a result of the mental attitude or psychology of the patient. We must bear in mind that we are dealing with a group of people who work daily or nearly so, year in and year out without respite, and who have but little opportunity for change, relaxation, or recreation. After an accident the claimant recognizes that he has had an injury and he may become acutely conscious of the fact that as a result of it he is suffering pain and disability. Perhaps he has barely escaped a very serious injury and he is sensitized and begins to give much thought to his body. This sensitization is exemplified in the custom among structural ironworkers all of whom on a given job will stop work for the day when one of their men falls from a height. The laborer also interprets the compensation law as indicating that the state is obligated to him, owes him a debt of support, and his injury is his passport to enter the realm of compensation. It may also be the claimant's first opportunity to have a vacation, and he is anxious to prolong it. The patient's nervous system may be severely upset so that he is unusually susceptible to discomfort of all kind. I recently had a rather sturdy Swedish laborer who injured his back and fractured one lumbar transverse process. His convalescence progressed satisfactorily and at the end of several months I expected him to return to work. As the weeks passed, however, he became fretful. He feared that his back was going to be permanently disabled. This was fostered by the fact that when he tried to lift a chair he had pain in his back, and he concluded that he had a permanent disability. This led him to brood and he became melancholy. Our efforts to cheer him were in vain. He gradually became mentally unbalanced and he is at present, eighteen months after his injury, still out of work and a charge on the state and on the insurance carrier.

Finally, the disability and the period of compensation may be prolonged because the patient has lost self-confidence. A window cleaner or structural ironworker, for instance, falling from a height and sustaining minor injuries, may get well of his injuries in a short time, but having lost confidence in himself he may not be able to return to his original occupation for a long time. This fact is

thoroughly appreciated by all insurance carriers who always allow an extra period of time in which to permit the claimant to regain his self-reliance.

Disposition of Case

Appreciating the numerous factors inherent in the nature of the injury and in the mental attitude of the patient which tend to prolong the convalescence in a compensation case, we must be extraordinarily careful to apply quickly and expertly the best remedial measures. I believe that one drawback in the successful management of a compensation case is due to the fact that some insurance carriers are very nearsighted financially, and believe that they profit by employing inexperienced physicians, because they can buy the services of such men with small payments. That this is a fallacy can be seen from the favorable statistics of some of the large establishments, factories, mills, and mines where the most expert physicians and surgeons are employed. It is evident that expert service which is available at the time of the accident is much more valuable than expert service when called in months or years after the accident, and when the pathologic conditions, which might readily have been eradicated if treated early, have been permitted to take root and to produce permanent and irreparable damage.

It is disheartening to enter a compensation bureau and face the large number of inexperienced and indifferent physicians in whose hands and to whose judgment innumerable patients are intrusted. Many physicians seek compensation cases as a means of temporarily making a living while they are attempting to develop a practice in general medicine or to develop a reputation in some special field. Industrial surgery is a highly specialized form of surgery and requires special training just as does any other specialized field. What we actually find, however, is that recent graduates do most of the work, often without any supervision, as if a fracture of the femur, a juxta-articular injury of the phalanges, a fracture of the spine, and an infection of the hand are simple lesions easily managed. I am in accord with Dr. William O'Neill Sherman of Pittsburgh who, in a recent article[1] on treatment of fracture of the femur, repeatedly insists that he who undertakes to treat an injury must prove that he is equal to the job. The fault lies both with the doctors who seek unusual financial reward without adequate preparation or ability and with the insurance carriers who desire at the end of the year to show to the management that they have had a small medical bill.

To emphasize this point I should like to cite the instance of a recent graduate of my acquaintance who spent six mornings a week at a large industrial clinic. For this work he received $100 a month, or about $4 for a morning during which he examined and treated on the average thirty patients. This represents an average expenditure for medical treatment of about 10 cents per patient. The pathetic feature of it all is that the

[1] Sherman, W. O'N.: Operative Treatment of Fractures of the Shaft of the Femur with Maximum Fixation. Jour. Bone and Joint Surg., 1926, N. S. *8*, 494.

patient got only 10 cents' worth of service and no more.

In the ordinary course of events, in the treatment of cases of backache resulting from industrial accidents, not all are cured; some are only improved. This group interests us particularly, for sooner or later it is appreciated by all that so far as further improvement is concerned the case is at a standstill, and a radical change is necessary. I believe that in a case of chronic backache, when efficient and expert treatment has been provided for a sufficient time and the maximum improvement has been obtained, and when further treatment because of the nature of the lesion or the psychology of the patient will be of no avail, it is not only advisable but desirable and highly beneficial to settle the case. This will have a wholesome effect on the patient from many aspects, and at the same time will remove the claimant as a charge upon the insurance carrier. When a case is settled, the claimant promptly realizes that he can no longer go to complain to the company's physician, that he cannot expect any further assistance from him or from the company, and that he must depend on his own resources; hence he rapidly again becomes self-reliant. Being free to do as he pleases, the claimant will, in the event of a disability, thoughtfully turn to a less hazardous occupation, and one to which he is now fitted. Often, too, a settlement means that the claimant is given a lump sum of money which may enable him to enter a small business requiring light labor, but yielding a satisfactory income. Thus, a settlement of a case is beneficial because it leads to a healthier state of affairs. The claimant desensitizes and rehabilitates himself by exerting greater effort and by engaging in labors to which he is equal and in which he can obtain a livelihood.

THE WET KATA-THERMOMETER AS AN INDEX OF THE SUITABILITY OF ATMOSPHERIC CONDITIONS FOR HEAVY WORK*

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INTRODUCTION

IN a previous article in THIS JOURNAL (1) I endeavored to show that for most purposes the cooling power of the air, as estimated by the dry kata-thermometer, affords a better index of comfortable sensations than does the effective temperature, as estimated by the two-chamber method (Pittsburgh). My chief arguments in favor of cooling power determinations were that they automatically make a considerable allowance for acclimatization, while on the other hand effective temperatures make no allowance at all. It is obvious that if the subject of experiment is moving back and forth between two chambers, one of which has a higher temperature and higher air velocity than the other, he cannot become acclimatized to either set of conditions. Yet Yaglou (2), in a succeeding article to mine, maintained that the effective temperature index "takes *due* account of acclimatization," while the kata takes no account of acclimatization. Further, when I pointed out that observations made on many hundreds of subjects indicated that, owing to acclimatization, a given sensation of comfort experienced during the summer corresponded to a lower cooling power than that required in the winter, while the effective temperature method indicated that it ought to be higher, Yaglou completely confused the issue by assuming that a kata with a *clothed* bulb ought to be used in certain of the observations. It is almost needless to say that our cooling power observations and calculations at all times relate to one and the same instrument, namely, the *naked* dry kata-thermometer. This instrument I have repeatedly calibrated against various experimental air velocities and temperatures, and it is the only one concerned in our discussion.

I pointed out in my article that the cooling power—as estimated by dry kata-thermometer—applies only to individuals engaged in light work at ordinary temperatures. For those engaged in heavy work, and especially for those working at high temperatures, the readings of the *wet* kata-thermometer are a better index of comfort and of the suitability of working conditions. Such individuals would be covered with perspiration, and would therefore react to variations in the velocity, temperature, and humidity of the air in a somewhat similar manner to that in which the wet muslin-covered bulb of the kata reacts to them. I did not record any experimental data in support of my contention, as there were none available, but I have recently, in conjunction with

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T. Bedford and C. G. Warner (3), made an investigation on the efficiency of coal miners in relation to atmospheric conditions, and these results fully support my claim that the wet kata cooling power is the best available index of comfort and of the suitability of working conditions.

Working Capacity of Coal Miners in Relation to Wet Kata Cooling Power

The determination of the working capacity of coal miners cannot be arrived at by the familiar method of measuring output, for the ease with which the coal is obtained varies greatly from day to day, and even from hour to hour, in the same working place. It varies still more in different working places in the same seam, while in different seams the working conditions may be so different that output comparisons may be absolutely futile as a measure of working capacity. We were therefore driven to devise tests which would apply almost equally to all colliers, whatever the ease or difficulty of their working places. The tests adopted were two in number: *viz.*, a rest pause test, and a tub filling time test.

As the result of observations in various heavy industries (4), we found that the men invariably take short rests from work every few minutes, and that the more arduous the work is, the longer and the more frequent are the rests. They are taken spontaneously, in consequence of fatigue, and their duration affords a measure of the fatigue experienced. We have obtained evidence in support of this statement by making systematic observations on colliers in various working places in two pits. In one pit the workings visited varied in depth from 540 feet to 2,715 feet, and the temperature, from 63° (dry bulb) and 59° (wet bulb) to 89° (dry bulb) and 82° (wet bulb). In the other pit the workings varied in depth from 1,450 feet to 2,200 feet, and the temperature, from 77° (dry bulb) and 69° (wet bulb) to 87° (dry bulb) and 80° (wet bulb). We usually remained at a working place for about three hours, and, after setting up our kata-thermometer apparatus at a spot as near as possible to where the collier was usually standing, we systematically noted down the rest pauses taken by the collier or colliers present for the next two hours or so. We divided these rests into three categories, according as they were (*a*) purely voluntary, (*b*) involuntary (due mostly to the fact that the men sometimes had to wait for tubs into which to load the coal), or (*c*) due to time spent in talking about work with a mate or foreman. We made rest pause observations on 138 miners altogether, for an average period of ninety-six minutes each, the twenty-minute meal time, which was always taken in the course of the morning, being ignored.

In addition to the rests, we noted the time taken to fill the tubs with coal. These tubs held half a ton each, and took 6 to 15 minutes to fill, 8 to 9 minutes being the most usual time. On an average we ascertained the time taken to fill 5.2 tubs at each working place.

In Table 1 we have classified our results in six groups according to the wet kata-thermometer cooling power of the air. This ranged from 18.6 to 6.4 in the various groups, and it will

be seen that, as it fell, the total rest pauses taken by the men gradually increased from 7.3 minutes per hour to 22.4 minutes, while the tub filling time increased from 8 minutes to 9.6 minutes. It seems reasonable to assume that if the men took 20 per cent. more time to fill a tub when the conditions were unfavorable than when they were favorable, they would slow down their rate of hewing coal and of doing other work to a similar extent. The actual working capacity of the men would therefore be proportional to working time per hour divided by tub filling time. Converting the working capacity so assessed into percentages, we see from Table 2 that under the most unfavorable atmospheric conditions the working capacity of the men was only 59 per cent. as great as under the most favorable conditions. The results are plotted out as continuous lines in Figure 1, and it will be seen that the working capacity fell off at a more and more rapid rate as the wet kata cooling power diminished, the fall being especially rapid when the cooling power dropped from 9 to 6.4.

TABLE 1.—REST PAUSES AND TUB FILLING TIMES IN RELATION TO WET KATA COOLING POWER

RANGE OF WET KATA COOLING POWER	NUMBER OF OBSERVATIONS	TOTAL RESTS	TUB FILLING TIME	TEMPERATURE		KATA COOLING POWER		AIR VELOCITY	EFFECTIVE TEMPERATURE
				Dry Bulb	Wet Bulb	Dry	Wet		
		min. per hr.	*min.*	*°F.*	*°F.*			*ft. per min.*	*°F.*
19 to 16.....	10	7.3	8.0	73.5	66.0	5.6	18.6	87	65.8
15 to 14.....	16	6.7	8.6	70.1	65.6	4.8	14.6	34	65.8
13 to 12.....	17	9.0	8.5	81.7	73.6	3.1	12.9	46	75.3
11 to 10.....	47	10.0	9.2	80.8	74.1	2.8	10.8	25	75.8
9 to 8.....	42	11.1	9.1	82.4	76.2	2.4	9.0	18	77.8
7 to 5.....	6	22.4	9.6	86.2	79.3	1.7	6.4	10	81.2

TABLE 2.—WORKING CAPACITY IN RELATION TO WET KATA COOLING POWER

MEAN WET KATA COOLING POWER	WORKING TIME	TUB FILLING TIME	RATE OF PRODUCTION
	min. per hr.	*min.*	
18.6	52.7	8.0	52.7÷8.0=6.59=100
14.6	53.3	8.6	53.3÷8.6=6.20= 94
12.9	51.0	8.5	51.0÷8.5=6.00= 91
10.8	50.0	9.2	50.0÷9.2=5.43= 82
9.0	48.9	9.1	48.9÷9.1=5.37= 81
6.4	37.6	9.6	37.6÷9.6=3.92= 59

Working Capacity of Coal Miners in Relation to Effective Temperature

Accompanying the fall in wet kata cooling power, there was a rise in the dry bulb and wet bulb temperatures, and a fall in the air velocity. Hence there was inevitably a rise in the effective temperature, which combines

these three variables into a single expression. The effective temperature increased from 65.8° to 81.2°, or through 15.4°, which is somewhat greater than the rise shown by the dry bulb and wet bulb temperatures, and this fact might be taken to show that the effective temperature was at least as good a measure of the atmospheric conditions as the wet kata cooling power, if not a better one. However, when the data were reclassified on the basis of effective temperature, as in Table 3, it will be seen that they show a smaller variation in the rest pauses taken, while the tub filling time is almost unaffected. In consequence, the working capacity of the men, instead of falling off 41 per cent. as it did when the results were calculated on the wet kata basis, shows a fall of only 10 to 15 per cent. The much less striking relationship of working capacity to effective temperature than to wet kata cooling power is well brought out by comparing the dotted line curves in Figure 1, which relate to effective temperature, with the continuous line curves, which relate to wet kata cooling power.

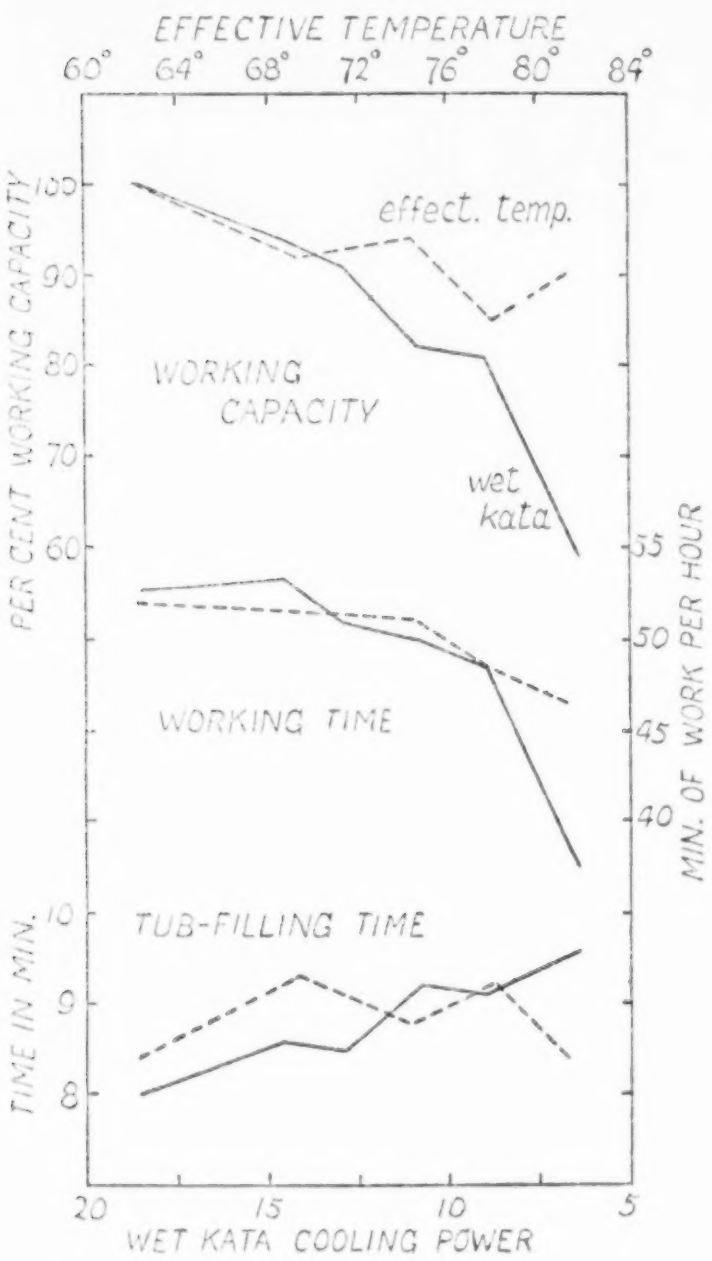

FIG. 1.—Working capacity in relation to wet kata cooling power and to effective temperature.

Probably the effective temperature index considerably underestimates the importance of air velocity in its influence on working capacity, and there is reason for thinking that the wet kata cooling power likewise underestimates it to some extent, though not so much as effective temperature does. On splitting up groups of the data (previously classified on the wet kata basis) into two halves, according as the air velocity was low (under 25 feet per minute) or high (over 26 feet per minute), the results shown in Table 4 were obtained. It will be seen that in the high velocity group the men took shorter rest pauses and less time to fill tubs than they did in the low velocity group. In consequence, their working capacity was 8 per cent. greater; and this in spite of the fact that the effective temperature was 5.7° higher. The wet kata cooling power was practically the same in the two groups, so it erred to some extent as an index.

Again, when the results were classified on the basis of *dry* kata cooling power, it was found that the working capacity varied more widely than

TABLE 3.—REST PAUSES AND WORKING CAPACITY IN RELATION TO EFFECTIVE TEMPERATURE

RANGE OF EFFECTIVE TEMPERATURE	NUMBER OF OBSERVATIONS	TOTAL RESTS	TUB FILLING TIME	RATE OF PRODUCTION	TEMPERATURE		KATA COOLING POWER		AIR VELOCITY	EFFECTIVE TEMPERATURE
					Dry Bulb	Wet Bulb	Dry	Wet		
°F.		*min. per hr.*	*min.*		°F.	°F.			*ft. per min.*	°F.
Under 68	17	8.0	8.4	100	64.5	62.2	5.7	15.2	18	62.1
68 to 71	10	7.0	9.3	92	77.2	68.6	4.5	15.6	73	69.5
72 to 75	41	8.9	8.8	94	78.7	73.2	3.3	11.4	27	74.4
76 to 79	54	11.5	9.2	85	83.9	76.0	2.4	10.1	30	78.0
80 or more	16	13.4	8.4	90	87.3	79.5	1.8	8.5	27	81.3

TABLE 4.—INFLUENCE OF AIR VELOCITY ON WORKING CAPACITY

	AIR VELOCITY	
	Low	High
Rests (min. per hr.)	9.6	7.8
Tub filling time (min.)	9.0	8.6
Rate of production	50.4÷9.0= 5.60 (=100)	52.2÷8.6= 6.07 (=108)
Temperature (°F.) Dry bulb	74.1	83.1
Temperature (°F.) Wet bulb	69.2	74.9
Kata cooling power Dry	3.8	2.9
Kata cooling power Wet	12.4	12.1
Air velocity (ft. per min.)	15	51
Effective temperature (°F.)	70.6	76.3

when they were classified on the basis of effective temperature. The average dry kata values of the successive groups, and the corresponding rates of production, were the following:

Dry Kata Cooling Power	*Rate of Production*
7.0	100
5.3	85
4.5	93
3.3	84
2.3	74
1.6	75

Probably this seemingly greater dependence of working capacity on dry kata cooling power (which contains no wet bulb temperature factor) than on effective temperature (which does contain a wet bulb factor) is due to the fact that the dry kata cooling power makes a much larger allowance for air velocity than effective temperature does.

Another method employed for testing the correctness of the effective temperature index was to split up groups of data (previously classified on the wet kata basis) into two halves, according as the effective temperature was low or high. From Table 5 it will be seen that the low temperature group had an effective temperature

6.5° lower than the high temperature group, and apparently in correspondence with this fact both the rest pauses taken and the tub filling times were rather shorter. Taken together, they showed a working capacity which was 7 per cent. higher than that of the high effective temperature group; but a portion of this increment must have been due to the somewhat greater wet kata cooling power observed in the low temperature group than in the high one.

TABLE 5.—INFLUENCE OF EFFECTIVE TEMPERATURE ON WORKING CAPACITY

		EFFECTIVE TEMPERATURE	
		Low	High
Rests (min. per hr.)		9.1	10.1
Tub filling time (min.)		8.6	9.0
Rate of production		50.9÷8.6= 5.92(=107)	49.9÷9.0= 5.54(=100)
Temperature (°F.)	Dry bulb	75.0	84.5
	Wet bulb	70.4	76.3
Kata cooling power	Dry	3.7	2.4
	Wet	11.4	10.9
Air velocity (ft. per min.)		18	37
Effective temperature (°F.)		71.6	78.1

The data have been grouped and tested by other methods in addition to those mentioned (*cf.* (3)), but it is unnecessary to quote them at length. The general conclusion arrived at is that the wet kata cooling power, though not a perfect index of working capacity, is much better than any other available index such as effective temperature. Now the wet kata cooling power, in contradistinction to the effective temperature index, depends only on the wet bulb temperature of the air and on air velocity, and is not affected by the dry bulb temperature, except indirectly. This indirect effect depends on the fact that any rise or fall in dry bulb temperature automatically affects the wet bulb temperature. If, for instance, moist air with a dry and a wet bulb temperature of 70° is warmed till its dry bulb temperature reaches 80°, the wet bulb temperature automatically rises to about 74°. If it is warmed to a dry bulb temperature of 90°, the wet bulb temperature automatically rises to about 78°, and so on, each rise of 1° in the dry bulb causing a rise of about 0.4° in the wet bulb.

Influence of Muscular Work in the Laboratory on Effective Temperature

In apparent contradiction to our observations on coal miners, Houghten, Teague, and Miller (5) have recently found that when men are performing muscular work they are as much affected by the dry bulb temperature of the air as when they are resting. The investigation was made by the two-chamber method, in which the subjects passed back and forth be-

tween two chambers, in one of which the air was at a higher dry bulb temperature and lower relative humidity than in the other. The muscular work consisted in raising and lowering a 40-pound weight 5 feet, the operation being repeated seventy-five times in five minutes. For the next five minutes the subject passed back and forth between the chambers; then he repeated the weight raising. This procedure was continued for two hours. The effective temperatures observed, for subjects clothed in shirt and trousers, fell between those previously observed in resting subjects normally clothed and in resting subjects stripped to the waist. That is to say, the dry bulb temperature is apparently just as important a factor when heavy muscular work is being done as when it is not. It is to be remembered, however, that the effective temperature is an estimate of the sensation of *warmth* felt by the subject, and in the experiments in question it was presumably the warmth felt toward the end of a five minutes' rest from work, after the subject had passed back and forth several times when assessing his sensations, and not his sensation of warmth when actually performing the hard work. Again, the sensation of warmth is a comparatively immaterial point for a subject engaged in hard muscular work. What we really require to know is the influence of atmospheric conditions on working capacity, and it is almost impossible to ascertain this in the laboratory. Even if the weight raising (with a lighter weight) had been continued for six or eight hours instead of for two hours, it would not have been possible to ascertain the true influence of atmospheric conditions, unless the experiment had been repeated day after day; for a man can always, if he wills it, perform an excess of muscular work for a limited period which he would be quite unable to maintain regularly for several hours on a number of successive days. I found, for instance (6), that when pulling a dynamometer regularly at intervals of one and one-half seconds, my strength of pull fell to a certain level (ranging from 106 to 247 pounds according to the conditions) in the first four minutes, and then remained steady for as long as I cared to continue (*e.g.*, eighty-eight minutes), even though I felt myself getting more and more tired, and knew that I should feel fatigued the next day.

Hence a valid test of working capacity in relation to atmospheric conditions must be made under actual working conditions such as we observed in coal miners. Unfortunately it is difficult to find the particular conditions desired, but we are hoping to make further series of observations by our method in mines with considerable variations in the relative humidity of the air.

Air Conditioning in Mines

It is particularly desirable that further observations on working capacity in relation to humidity be made, as Yaglou (7) has made a claim for the air conditioning of mines which I believe to be erroneous. He suggests that the intake air should be conditioned by saturating it with moisture, for this procedure lowers the effective temperature by reducing the dry bulb temperature to the same level as the

wet bulb temperature. It does not alter the wet bulb temperature at all, but the method suggested implies that there is no special discomfort attaching to hard work in an atmosphere saturated with moisture. Though very little evidence on the subject is available, the instances recorded by Bruce (8) for temperatures experienced in mines and elsewhere at Sydney (see Table 6) suggest that even a moderate degree of humidity is undesirable if the temperature is high. Thus we see that air with a wet bulb temperature of 81° and 62 per cent. saturated was very unpleasant compared with air having a wet bulb of 82° but a low humidity. Perhaps a slight addition of moisture to the intake air of a mine would be useful if the air happened to be very dry, but even this step seems a very doubtful one. Hence it may be most misleading to argue on the subject of air conditioning from the standpoint of effective temperature.

TABLE 6.—SHOWING RELATION OF DEW POINT TEMPERATURE TO COMFORT AS RECORDED BY BRUCE (8)

TEMPERATURE		RELATIVE HUMIDITY	DEW POINT TEMPERATURE	SENSATIONS EXPERIENCED
Dry Bulb	Wet Bulb			
°F.	°F.	%	°F.	
111	82	24	66.0	Hard work done without discomfort.
77	75	89	73.5	Conditions depressing.
90	81	62	75.5	Efficient mental or physical work practically impossible.

Physiologic Importance of Effective Temperature Index

In addition to observations on the sensation of warmth, Yaglou and his colleagues investigated the effect of high temperatures on other physiologic reactions such as rectal temperature, pulse rate, and body weight. Yaglou maintains (7) that these reactions followed the effective temperature index as closely as could be expected, regardless of dry bulb or wet bulb temperature, or of relative humidity. He records a table of results (7, Table 1) obtained with three subjects at rest, stripped to the waist, and I am reproducing this table in part in Table 7, together with a few extra data taken from the original paper (9). The rise in rectal temperature forms the most reliable guide, and this alone is shown, owing to considerations of space. In some cases it has been corrected slightly, so as to allow for the small differences of effective temperature, and the proportional rise in rectal temperature at various humidities is recorded in terms of the rise observed in saturated air taken as 100. It will be seen that at a relative humidity of 60 per cent. the rate of rise was, on an average, as high as in air saturated with moisture, but at lower humidities it was smaller, especially when the air was only 15 to 5 per cent. saturated. Hence these data offer but imperfect support to Yaglou's contention. They also indicate—as has been pointed out by

Yaglou and his colleagues—that in any case the effect of the dry bulb temperature is small at high atmospheric temperatures. For instance, they show that at an effective temperature of 106° a rise of 51° in the dry bulb temperature is equivalent to a fall of only 5.6° in the wet bulb.

TABLE 7.—RISE IN BODY TEMPERATURE IN RELATION TO EFFECTIVE TEMPERATURE

EFFECTIVE TEMPERATURE	TEMPERATURE		RELATIVE HUMIDITY	RISE IN RECTAL TEMPERATURE	CORRECTED RISE IN RECTAL TEMPERATURE	PROPORTIONAL RISE IN RECTAL TEMPERATURE WHEN PERCENTAGE RELATIVE HUMIDITY WAS			
	Dry Bulb	Wet Bulb				100–91	60	30	15–5
°F.	°F.	°F.	%	°F. per hr.	°F.				
106.0	106.0	106.0	100	4.27	4.36	100	...	..	...
106.2	120.0	104.6	60	4.70	....	...	108	..	...
106.4	157.0	100.4	15	4.60	4.51	...	...	..	103
101.3	102.1	101.2	99	2.53	....	100	...	..	...
101.3	114.0	99.3	60	2.74	....	...	108	..	...
101.8	129.3	97.5	30	2.45	2.28	...	...	90	...
101.1	130.0	96.4	30	2.44	2.51	...	...	99	...
101.2	146.0	93.6	15	1.90	1.93	...	...	..	76
99.0	99.0	98.9	100	2.08	....	100	...	..	...
99.0	112.0	96.7	60	2.00	....	...	96	..	...
95.1	97.1	94.6	91	0.85	....	100	...	..	...
94.9	106.0	92.2	60	0.72	0.77	...	91	..	...
95.2	120.0	89.2	30	0.87	0.84	...	...	99	...
95.1	144.7	81.8	5	0.75	....	...	...	..	88
Mean						100	101	96	89

Conclusion

It appears that effective temperature, which was shown in a previous article to be inferior to the dry kata cooling power as an index of comfort for persons engaged in light work at moderate temperatures, is still less suitable for persons engaged in heavy work at high temperatures. For them the wet kata cooling power is found to be a far better index of the suitability of atmospheric conditions. It is true that effective temperature is stated to be an index of *warmth* rather than of the suitability of working conditions, but no object is gained in knowing the sensations of a man if they are not reflected in his capacity for work.

Such evidence as we possess indicates that it is an erroneous principle to condition the air of mines by increasing its relative humidity and lowering its dry bulb temperature, while leaving the wet bulb temperature unchanged. Air that is cooler

but more humid—though of a lower effective temperature—appears to be much more trying to work in than air that is warmer and less humid.

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TEMPERATURE, HUMIDITY, AND AIR MOVEMENT IN INDUSTRIES: THE EFFECTIVE TEMPERATURE INDEX*

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Introduction

IT is now well recognized that the atmospheric conditions in industries exert an important influence on the output and health of the workers. The suitability of the physical environment for work and comfort is not determined alone by the chemical purity of the air or by its temperature. Humidity and air movement as well have an important bearing, because they determine the heat loss by evaporation and convection.

A correct index of comfort must be based on the capacity of the environment to remove heat from the body. This is true because comfort depends largely on the maintenance of a proper balance between heat production from within and loss of heat from the skin. The body temperature is maintained as a result of this balance. Thus if heat loss is retarded, the temperature of the body rises, producing feelings of discomfort and depression and finally resulting in serious physiologic damage.

The evidence accumulated in recent years (1) (2) indicates conclusively that the body does not resemble either a dry or a wet bulb thermometer in its thermal properties. For this reason the kata-thermometer (3) was devised, which, it was supposed, closely approximated the thermal properties of the human body. More recent researches (4) (5), however, showed that it did not adequately represent the true condition.

In seeking for an exact thermal index of atmospheric conditions (2), we ascertained what combinations of temperature, humidity, and air movement produced sensations of equal warmth and then evaluated these combinations in a single index called the "effective temperature index." It was found subsequently that various physiologic responses were apparently stimulated by and regulated in accordance with this index.

Effective Temperature Index

Effective temperature is not a temperature in itself, which, like dry or wet bulb temperatures, can be measured by ordinary thermometers; it is an arbitrary index of the sensation of warmth experienced as the result of temperature, humidity, and air motion; it combines these three factors into a single value. This index

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was determined experimentally at the Research Laboratory of the American Society of Heating and Ventilating Engineers at Pittsburgh, Pa., by comparing sensations produced by different combinations of temperature, humidity, and air movement in two adjoining rooms. These rooms were especially designed for this purpose and were equipped with modern air conditioning apparatus by means of which any desired temperature, humidity, and rate of air movement could be maintained.

The principle underlying the effective temperature index is that, for any given degree of warmth or comfort, the temperature, humidity, and velocity of the air may vary considerably, so long as their combined effect remains the same. For instance, if the temperature of the air is increased, either its humidity must be correspondingly decreased, or its movement increased, in order that the sensation of warmth may remain unchanged. All combinations which induce identical sensations of warmth have, of course, the same effective temperature value. This index can be computed by means of the charts in Figures 1 and 2 when the dry and wet bulb temperatures and the rate of air movement are known.

The Pittsburgh laboratory has, at the present time, developed two separate and distinct effective temperature scales. The first (6) (7) or basic scale (Fig. 1) was determined by subjects stripped to the waist and applies to hot industries. The second (8) or normal scale (Fig. 2) is of more practical importance, because it applies to men normally clothed. In both studies the subjects were engaged in light occupations.

Controversy on the Kata-Thermometer and the Effective Temperature Index

In a recent paper (9), Vernon takes exception both to the experimental procedure and to the interpretation of the Pittsburgh results, stating that the method by which the effective temperature index was determined was unnatural and therefore impractical and that the index takes no account of acclimatization. Vernon therefore concludes that "the kata probably yields as fair an index of comfort as is obtainable."

These criticisms of Vernon's have been discussed elsewhere (10). It was shown that the effective temperature index was based fundamentally on a sound physiologic principle, namely, that all bodily responses to atmospheric heat are initiated and mediated through the temperature senses of the skin. The practical value of the effective temperature index was demonstrated and it was shown that the conflicting results obtained by the two methods could be harmonized quantitatively by changing Vernon's data, obtained with the kata, to allow for the influence of clothing, humidity, and air movement.

In one of the controversial papers (9), Vernon's statements seem to disagree with the exceptions he has formerly taken. Under the caption (p. 400) "Effective Temperature as a Measure of Actual Cooling of the Body," he states: "I have recently made a number of observations on the cooling effect of air movement by an

entirely different method, and my results, in so far as they are comparable, are in good agreement with the effective temperature data." In a very recent paper (11, p. 30) he states: "Information tending to support the correctness of effective temperature as an index of comfort when the subjects are resting or doing very light work, was obtained by us in an indirect manner." In his opinion, however, this index does not hold when heavy muscular work is performed. This last criticism of Vernon's is discussed later in this paper.

Comfort Zone

The comfort zone for men stripped to the waist (12) was determined at this laboratory from eighty-five experimental subjects (men). As will be seen in Figure 1, it comprises effective temperatures between 66° and 82° on the basic scale. The most probable optimum appears to be 72.5°. These values take into consideration both diurnal and seasonal acclimatization. Diurnal changes in adaptation to atmospheric conditions were accounted for by keeping the temperature constant for one-half to three-quarters of an hour before recording the subjects' sensations. This period seemed to be sufficient to overcome the influence of previous environments in the case of men stripped to the waist. Seasonal changes in adaptation to climate were accounted for by carrying on our experiments both in summer and in winter. Under the conditions of these experiments, we failed to detect evidence of seasonal acclimatization.

The comfort zone for people normally clothed (13) is shown in Figure 2. It was determined at the Pittsburgh laboratory by 130 subjects of both sexes, engaged in different occupations and wearing different types of indoor winter clothing. Conditions of maximum comfort are represented by the 66° effective temperature line on the normal scale. This zone applies to average American men and women living in the broad geographic belt across the United States in which central heating is necessary in winter. It does not apply to climates, clothing, and heating standards like those of Great Britain. In our opinion, the British comfort zone is lower than the American zone, largely on account of the difference in clothing, particularly in underclothing, worn in the two countries. In the United States, men generally wear medium weight or thin cotton underwear the year around. This we ascertained from a statistical study recently completed by this laboratory. Woolen underwear is seldom worn in the United States, because it is uncomfortable where the temperature of homes, offices, and factories is maintained at 65° to 75°.

Vernon (9, p. 393) attributes the variation of the British comfort zone to acclimatization, although in another paper (14) he gives an excellent discussion on the effects of clothing.

Influence of Clothing on the Comfort Zone

The influence of clothing on the comfort zone can be studied by com-

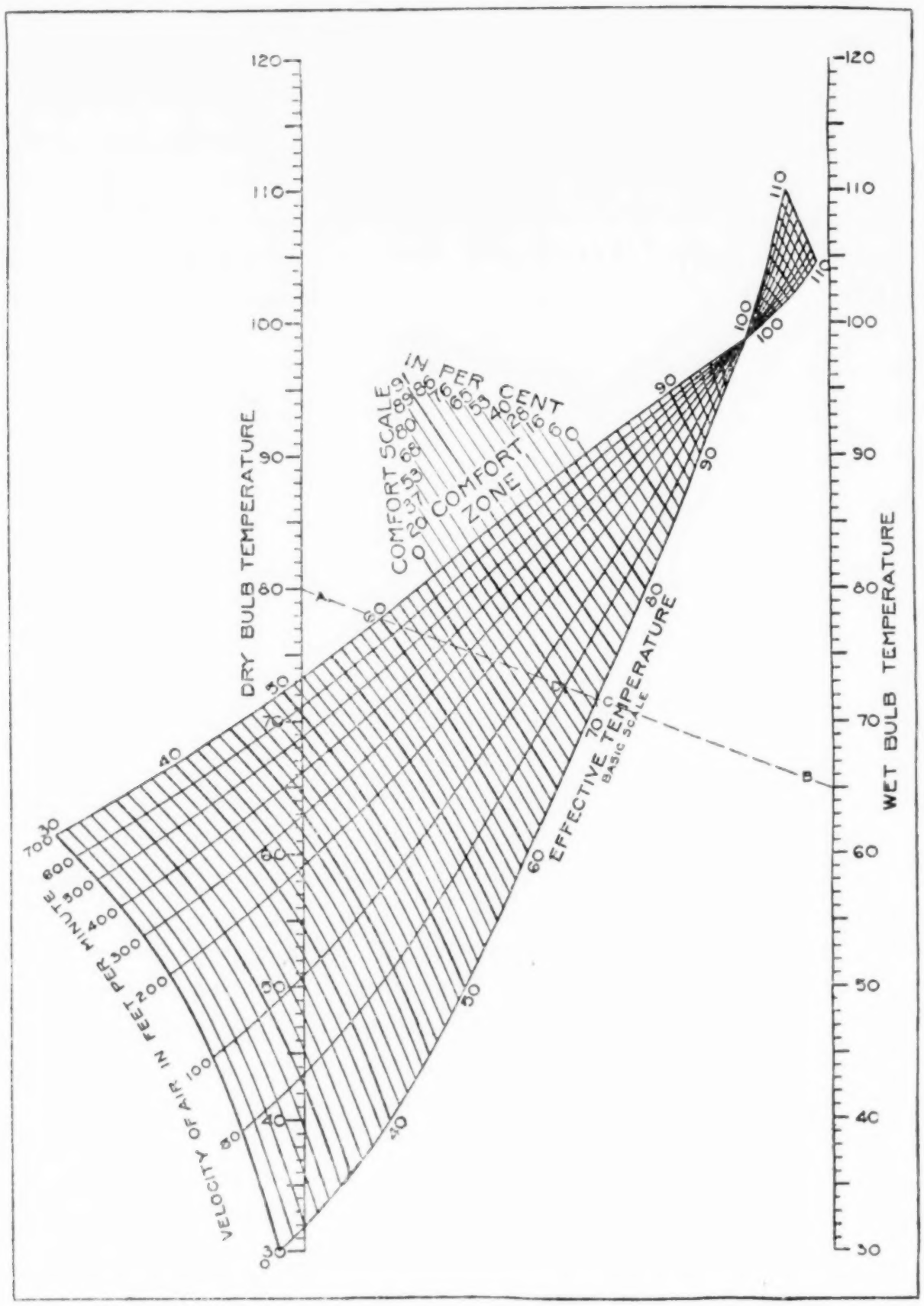

FIG. 1.—Thermometric chart showing basic scale of effective temperature.

Example in Use of Chart

Given dry bulb 80°, wet bulb 65°, velocity of air 50 feet per minute.

1. Draw line AB. Its intersection with the 50-foot velocity curve at D gives 70° for the effective temperature of the condition.
2. Follow line AB to C and read 71.6° for the effective temperature with still air.
3. The cooling produced by the movement of the air is:

$$71.6° - 70° = 1.6°$$ effective temperature.

paring the zones in Figures 1 and 2, as is done in Table 1. It will be observed that a temperature of 70° is required for comfort when ordinary indoor winter clothing is worn; whereas, with men stripped to the

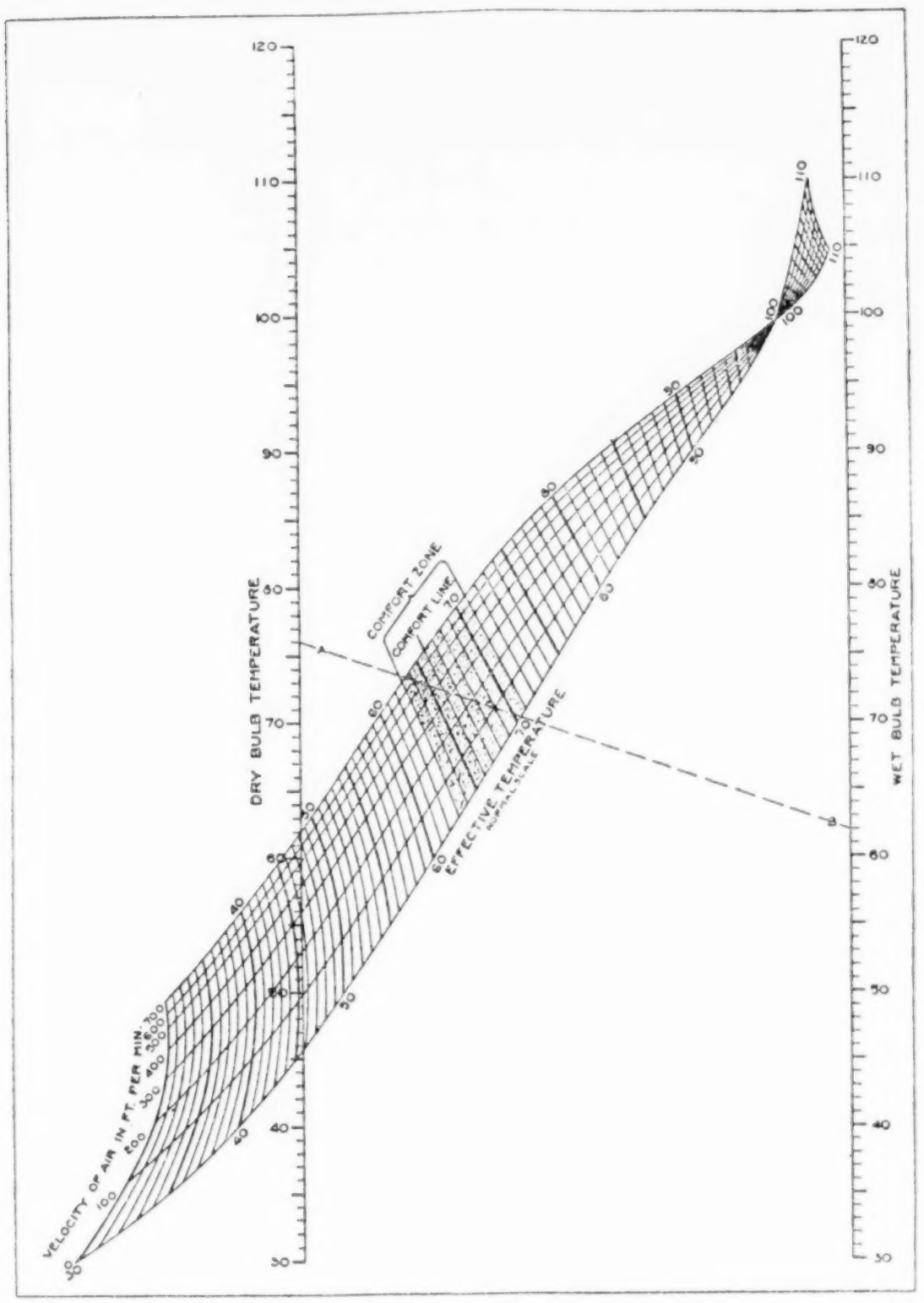

FIG. 2.—Thermometric chart showing normal scale of effective temperature.

Example in Use of Chart

Given dry bulb 76°, wet bulb 62°, velocity of air 100 feet per minute, determine: (1) effective temperature of the condition; (2) effective temperature with still air; (3) cooling produced by the movement of the air; (4) velocity necessary to reduce the condition to 66° effective temperature.

1. Draw line AB through given dry and wet bulb temperatures. Its intersection with the 100-foot velocity curve gives 69° for the effective temperature of the condition.

2. Follow line AB to the right to its intersection with the 0 velocity line, and read 70.4° for the effective temperature with still air.

3. The cooling produced by the movement of the air is:

$$70.4° - 69° = 1.4° \text{ effective temperature.}$$

4. Follow line AB to the left until it crosses the 66° effective temperature line. Interpolate velocity value of 340 feet per minute, to which the movement of the air must be increased for maximum comfort.

waist, the temperature must be increased to 80°.

TABLE 1.—EFFECT OF CLOTHING ON TEMPERATURE LIMITS OF COMFORT ZONE

(Relative humidity 50 per cent.)

COMFORT ZONE LIMITS	SUBJECTIVE SENSATIONS	DRY BULB TEMPERATURE (°F.)	
		Subjects Normally Clothed (Men and Women)[1]	Subjects Stripped to Waist (Men)
Probable lowest	Cold	62.3	72.0
Probable optimum	Very comfortable	70.0	80.0
Probable highest	Too warm	80.0	91.8

[1] According to the Pittsburgh experiments (13).

In other experiments (12), we found that, when the subjects were dressed according to the season, the most probable optimum temperature in summer was about 6° higher than that in winter. Apparently this was due largely to clothing and to a less degree to acclimatization.

Vernon arrives at the same general conclusion by kata. He states (4, p. 57) ". . . . to produce a given sensation of air movement in winter required a cooling power about one unit higher than that required in summer. *This was due to acclimatization.* . . . . ."[1] We believe, therefore, that in overemphasizing the influence of acclimatization, Vernon underestimates the importance of clothing in this instance, although he himself has shown the marked extent to which clothing affects the sensations of warmth.

[1] Italics are mine.—C. P. Y.

Physiologic Responses of Men at Rest in Relation to Effective Temperature

The effective temperature index, which was derived from sensations perceived through the temperature senses of the skin, not only indicates sensations of warmth, but also determines the physiologic reactions of the body, in so far as such reactions are governed by the physical condition of the air. At the Pittsburgh laboratory (15) (16) (17) we have studied this phase thoroughly on men stripped to the waist, both at rest and at work. The data for men at rest, given in Figures 3 to 6, show that the physiologic reactions follow closely the effective temperature scale.

It will be observed that no appreciable changes occur until the effective temperature approaches 90°. When

that temperature is exceeded, the body apparently loses its heat equilibrium

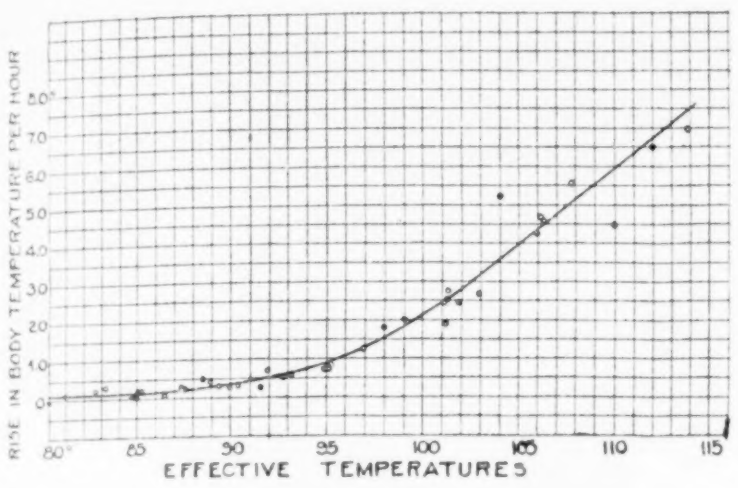

FIG. 3.—Correlation of effective temperature with the rate of rise in rectal temperature —°F. per hour; subjects at rest.

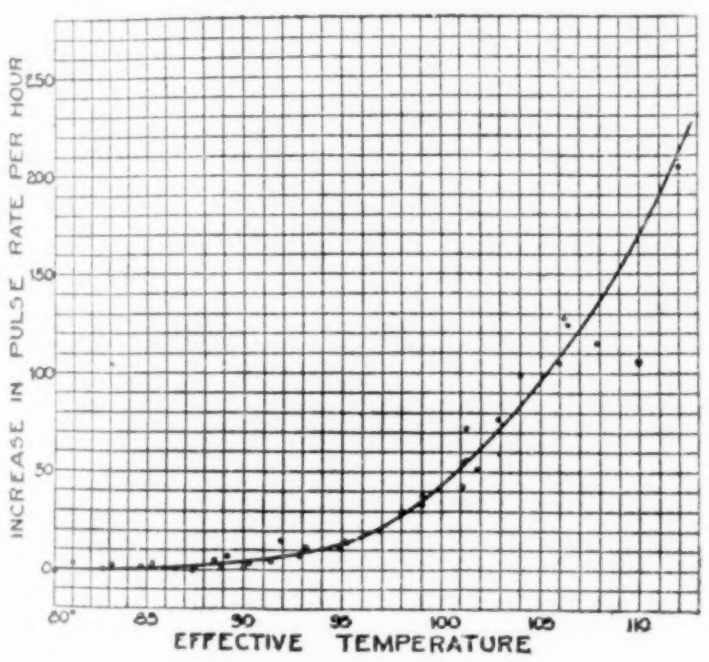

FIG. 4.—Correlation of effective temperature with the rate of increase in pulse frequency—beats per minute per hour; subjects at rest.

and the physiologic responses increase, not in direct proportion to effective temperature, but at a much more rapid rate. For men at rest and stripped to the waist, therefore, the upper limit of ability to compensate for atmospheric heat lies around 90° effective temperature.

Haldane (18) had previously concluded that the limit of endurance under similar conditions of exposure was in the neighborhood of 88°F. wet bulb, regardless of any other physical air factor. This is true only when the air is nearly saturated with moisture, that is, when both the dry and the wet bulb temperatures are

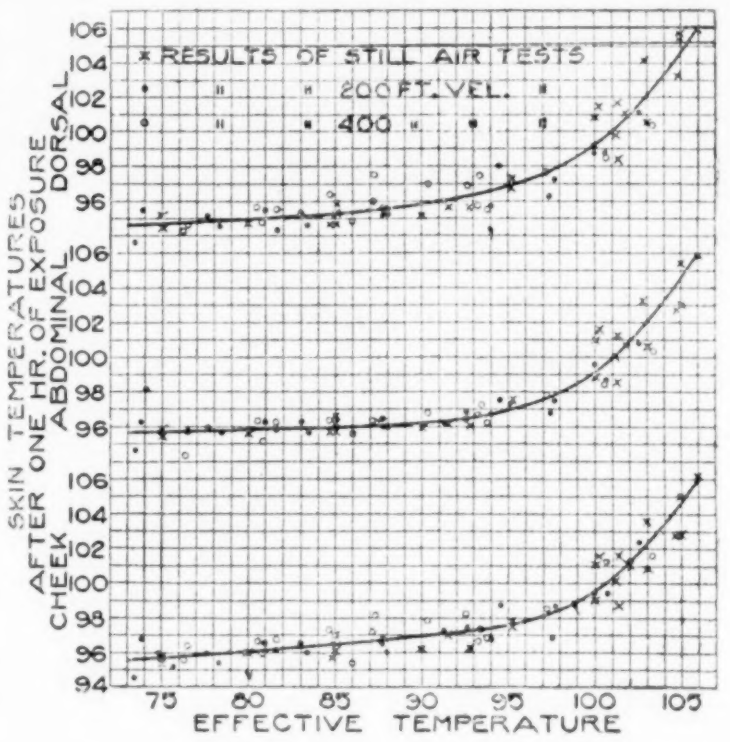

FIG. 5.—Correlation of effective temperature with the skin temperature after exposure of one hour—subjects at rest.

the same. With a wet bulb temperature of 88° but a dry bulb temperature of 140°, as can be seen from Figures 3 and 4, the body temperature will rise at the rate of 1.4°F. an hour and the pulse rate will increase at the rate of 25 beats a minute each hour, because the effective temperature is no longer 88° but 97.5°. Further evidence on this point is given in Table 2, which shows that, with constant effective temperature, the physiologic responses remain constant, whereas the dry and wet bulb temperatures, the relative humidity, and the dew point temperatures vary considerably. Therefore Haldane's statement should be modified by substituting the words "effective temperature" for "wet bulb temperature."

TABLE 2.—PHYSIOLOGIC RESPONSES OF MEN AT REST IN RELATION TO EFFECTIVE TEMPERATURE

TEST NO.	TEST ROOM CONDITIONS					PHYSIOLOGIC RESPONSES	
	Effective Temperature	Dry Bulb Temperature	Wet Bulb Temperature	Relative Humidity	Dew Point Temperature	Rise in Rectal Temperature	Increase in Pulse Rate
	°F.	°F.	°F.	%	°F.	°F./hr.	*beats per min./hr.*
56	106.0	106.0	106.0	100	106.0	4.27	105
72	106.2	120.0	104.6	60	102.2	4.70	128
80	106.4	157.0	100.4	15	89.1	4.60	124
53	101.3	102.1	101.2	99	101.1	2.53	56
76	101.8	129.3	97.5	30	91.1	2.45	52
78	101.1	130.0	96.4	30	89.4	2.44	54
79	101.2	146.0	93.6	15	80.1	1.90	43
44	95.1	97.1	94.6	91	94.1	0.85	14
58	94.9	106.0	92.2	60	89.0	0.72	10
74	95.2	120.0	89.2	30	81.0	0.87	14
81	95.1	144.7	81.8	5	54.0	0.75	13

Metabolism in Relation to Effective Temperature and the Comfort Zone

Figure 6 shows the basal metabolic rate at different effective temperatures. Contrary to what might have been expected, the basal metabolic rate increases with exposure to high temperatures as well as with exposure to temperatures below the normal. The increase at high temperatures is probably due to the warming of the body cells and the consequent increase in their chemical activity. Between effective temperatures of 75° and 83° lies a zone of minimum metabolism. This fact is important because it indicates that basal metabolism should be measured within this zone in order to eliminate the influence of the physical environment.

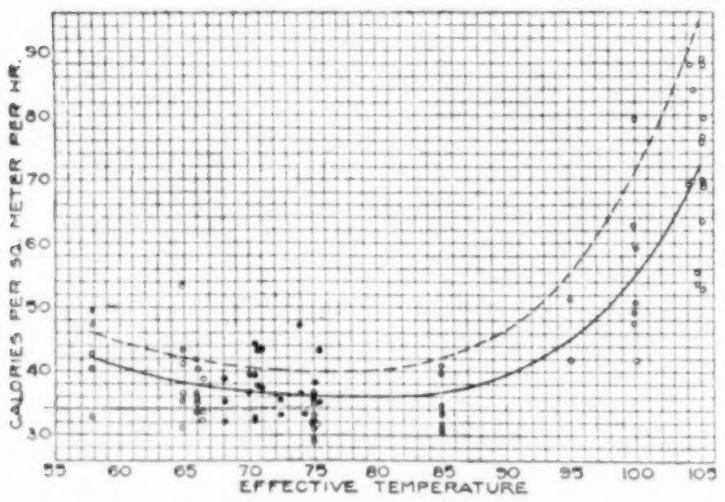

FIG. 6.—Correlation of effective temperature with metabolic rate. Solid line represents the basal metabolic rate. Broken line shows the effect of regular meals and sitting posture.

The dotted line in Figure 6 shows the increase in metabolism due to food and to sitting posture. These data were obtained under conditions of exposure similar to those in the comfort zone experiments with subjects stripped to the waist. It is interesting to note that the zone of minimum metabolism is identical with that of

comfort. Apparently metabolism and comfort are closely related.

Physiologic Responses of Men at Work in Relation to Effective Temperature

In one of his papers (11), Vernon gives data on the working capacity of coal miners in high temperatures. He concludes from these (p. 30) that the effective temperature index does not hold when heavy muscular work is performed, because the workers invariably stream with perspiration and in consequence react only to wet bulb temperature.

Until recently, we ourselves questioned the validity of the effective temperature index in instances involving heavy muscular work, since the index was determined by subjects engaged in light work. The latest experiments at the Pittsburgh laboratory (19), however, prove that the index was not substantially altered with heavy muscular work. Table 3 gives further evidence on this point. It contains data from the

TABLE 3.—PHYSIOLOGIC RESPONSES OF MEN AT WORK IN RELATION TO EFFECTIVE TEMPERATURE

TEST NO.	TEST ROOM CONDITIONS						PHYSIOLOGIC RESPONSES		TOTAL WORK DONE
	Effective Temperature	Dry Bulb Temperature	Wet Bulb Temperature	Relative Humidity	Dew Point Temperature	Air Movement	Rise in Rectal Temperature	Increase in Pulse Rate	
	°F.	*°F.*	*°F.*	*%*	*°F.*	*ft./min.*	*°F./hr.*	*beats per min./hr.*	*ft. lbs.*
32, 20 D	82.6	100.0	74.4	30	63.0	0 to 15	0.49	13	198,800
35, 18, 61, 53 D	82.0	90.2	78.2	59	74.0	0 to 15	0.50	12	210,000
20, 32, 16, 39 D	82.3	102.5	76.2	30	65.1	350	0.51	10	197,500
18, 35, 10, 33 D	81.7	95.0	82.7	60	78.6	350	0.59	14	192,500
40, 28, 6 D	90.2	107.5	84.5	39	77.4	0 to 15	1.54	39	136,400
33, 10 D	90.0	100.0	87.0	60	83.6	0 to 15	0.87	28	172,500
27, 2 D	90.0	90.0	90.0	100	90.0	0 to 15	1.54	55	130,000
6, 28, 5, 29 D	91.0	115.5	85.6	30	76.6	350	0.83	25	160,800
2, 27, 4, 34 D	90.2	92.7	92.7	100	92.7	350	1.65	40	126,750
25, 9 D	100.0	128.0	95.0	30	87.5	0 to 15	3.71	96	81,500
24, 3 D	100.0	100.0	100.0	100	100.0	0 to 15	4.21	108	51,700
3, 24 D	100.2	100.0	100.0	100	100.0	350	4.63	108	52,800
36, 8 D	110.4	143.0	107.5	31	102.1	0 to 15	8.45	213	37,500
23, 7 D	110.0	110.0	110.0	100	110.0	0 to 15	8.36	216	44,000
12, 26 D	109.0	120.0	104.8	60	102.6	350	8.48	227	33,800

Pittsburgh laboratory (16) (17) on the physiologic reactions of men working

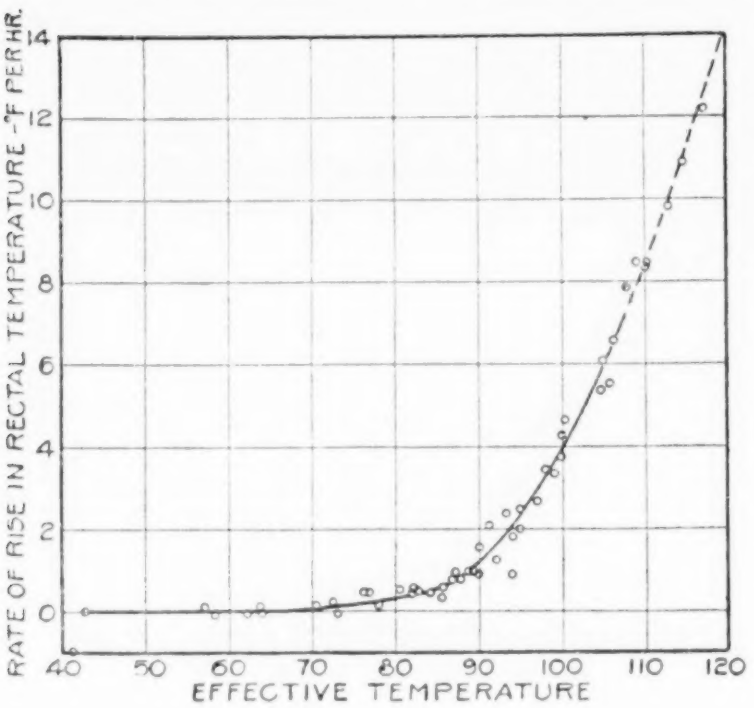

FIG. 7.—Correlation of effective temperature with rate of rise in rectal temperature—°F. per hour; subjects at work.

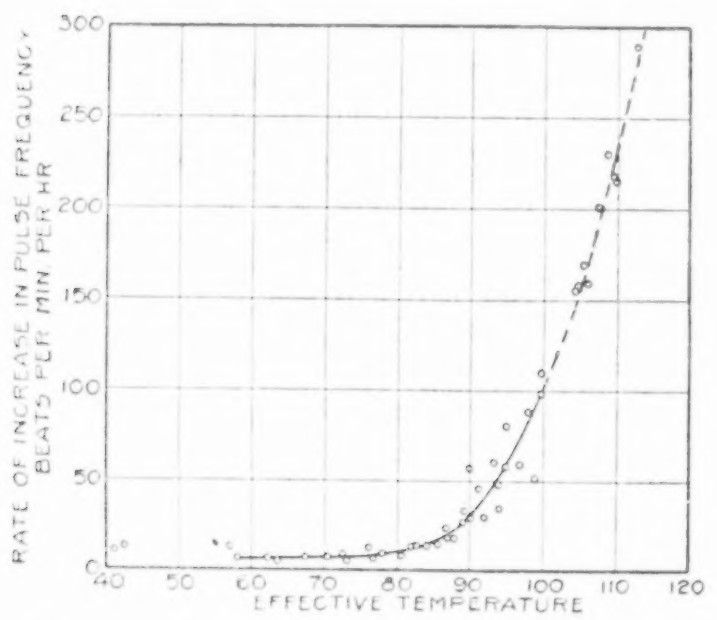

FIG. 8.—Correlation of effective temperature with the rate of increase in pulse frequency—beats per minute per hour; subjects at work.

at a rate of 90,000 foot pounds per hour in atmospheres of different temperatures and humidities with still and moving air. It is significant to note the close agreement between physiologic reactions and effective temperature, regardless of dry or wet bulb temperature, relative humidity, dew point temperature, or air movement. Even under the hottest conditions, effective temperature appears to be a more accurate index than wet bulb temperature or any other of the physical factors given in the table.

In the absence of the effective temperature index, wet bulb temperature seems to constitute the best index, but, within the limits of temperature which are of practical importance, dry bulb temperature is always of some significance.

Correlations of effective temperature with physiologic responses of men at work are given in Figures 7 and 8. These responses follow the scale of effective temperature as closely as those shown previously (Figs. 3, 4, and 5) for men at rest. It will be observed in Figures 7 and 8 that there is practically no change in the physiologic responses until the effective temperature reaches 75°, which appears to be the upper limit of men's ability fully to compensate for external temperature during heavy muscular work. Possibly 80° may be set as the extreme limit which can be endured without interfering with efficient work. If this value is exceeded, the body loses its heat equilibrium and serious physiologic reactions result, unless intermittent periods of rest are allowed for cooling off.

Acclimatization to High Temperatures and Adaptation to Muscular Exercise

In hot industries, especially in those involving heavy physical exertion, acclimatization and adaptability to muscular work should be taken into account. The first consists in man's

ability to adapt himself to changes in atmospheric conditions; the second, in his ability to train his muscles to perform a particular type of work.

If a man of sedentary habits were called upon to perform heavy manual labor in a hot atmosphere, his physiologic reactions would be much more severe than those of men accustomed to high temperatures and heavy manual work, until he too became adapted to those conditions. We found acclimatization to be so important at high temperatures that, in all our experiments, the subjects underwent a severe course of training before their data were accepted as reliable.

Work Output in Relation to Effective Temperature

Figure 9 illustrates the financial significance of maintaining proper temperature conditions in industries. Between effective temperatures of 40° and 75°, the amount of work performed is practically constant, in spite of the fact that sensations of comfort vary. Above 75°, the output falls off gradually until 80° is exceeded, when the fall becomes very rapid. According to these data, men can produce almost twice as much work at an effective temperature of 70° as they can at 93°. Since this latter condition is not uncommonly prevalent in hot industries like mining or the steel industry, the practical importance of reducing the temperature level is apparent.

From Figures 7, 8, and 9, we conclude that, in heavy industrial occupations, it is inadvisable, both from the point of view of efficient operation and from the point of view of the health and comfort of the workers, to

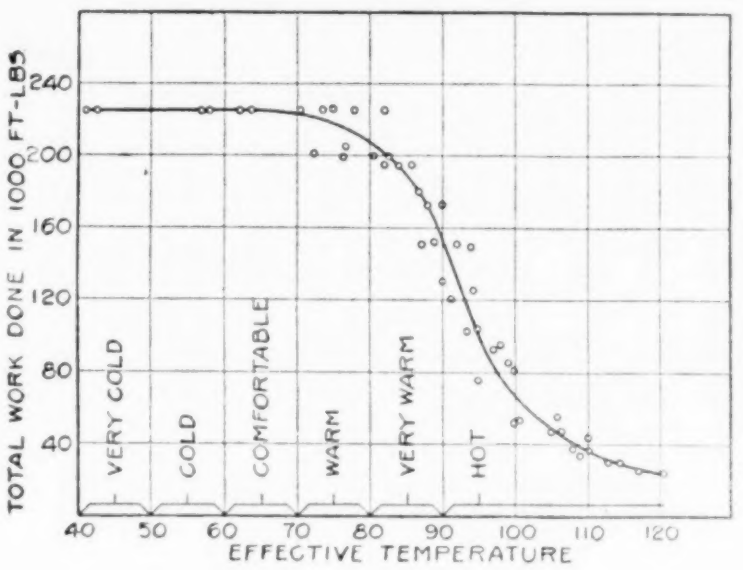

Fig. 9.—Work output in conditions of different effective temperatures.

allow the effective temperature to exceed the 80° limit; and that, in order to secure the best results, this limit should be reduced to 75°.

Influence of Air Movement and of Clothing on Output

The beneficial effect of air movement in increasing the output is shown in Figure 10. At dry bulb temperatures from 90° to 110°, an air movement of 350 feet a minute increased the output roughly 70 per cent. when the work is based on equal increase in the pulse rate, and roughly 30 per cent. when based on equal rise in rectal temperature. As an average, the output almost doubled when the air movement was 350 feet a minute. Above 110° dry bulb, the benefit derived from air movement becomes smaller and smaller, because the effective temperature approaches the temperature of the body.

Clothing also is an important factor, as has already been pointed out in connection with the comfort zone.

In another paper (8, p. 98) it was shown that ordinary clothing reduces

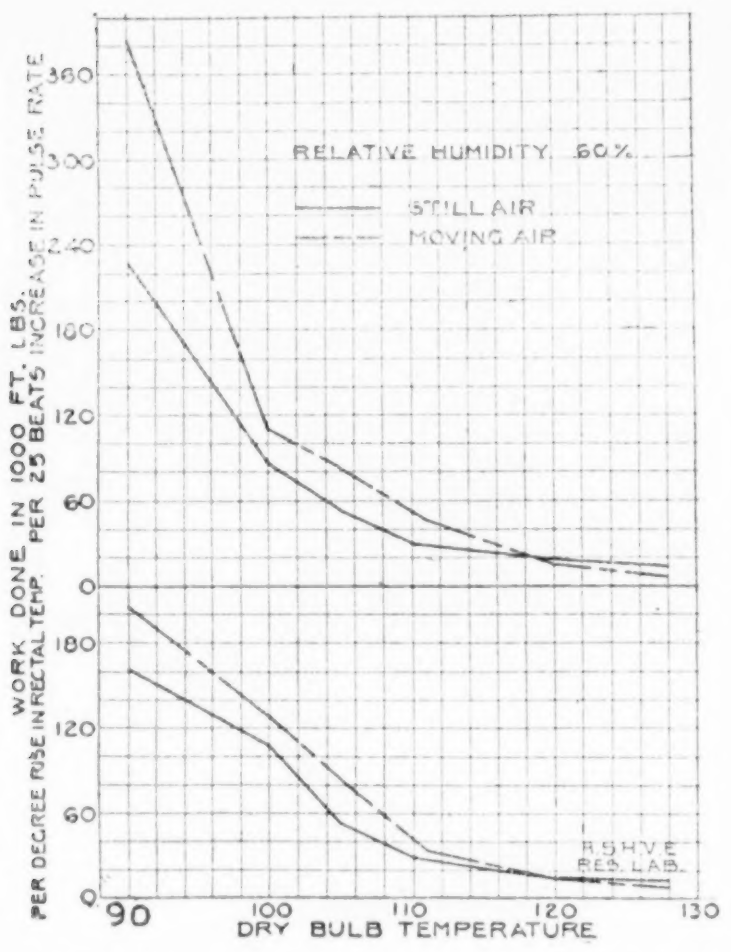

FIG. 10.—Influence of air movement (350 feet per minute) on work output.

the cooling power of the air by 50 per cent. as compared with data obtained on men stripped to the waist. The importance of stripping to the waist in hot industries is obvious, provided the effective temperature does not exceed the temperature of the body.

CONCLUSIONS

In industrial establishments where temperature is an important factor, it is advisable to judge the working conditions in terms of effective temperature. Effective temperature can be computed from dry and wet bulb temperatures and from the velocity of the air; it is the most exact index we have yet been able to devise for evaluating the thermal condition of the atmosphere. All measurable physiologic effects of the physical environment for men at rest and at work correlate well with this index. Even when profuse perspiration comes into play, effective temperature continues to be a more accurate index than wet bulb temperature.

Under special conditions and within narrow limits, the kata-thermometer constitutes a fair index of the thermal conditions of the atmosphere, although it requires empirical graduation. In most instances, however, its thermal properties differ so much from those of the human body that it is doubtful whether it can be compared in accuracy with the effective temperature index.

For the average American sedentary worker, an effective temperature of 66° on the basic scale proves most satisfactory. This value varies, however, to some extent with the season. In hot industries where light work is being carried on, the upper limit of one's ability to compensate for external temperature is an effective temperature of about 90°; in occupations involving hard manual labor, the limit is about 80°.

Provided the effective temperature is below 99°, the atmospheric conditions in hot industries can be improved by increasing the velocity of the air and by reducing the amount of clothing worn. Cooling the air by means of adiabatic saturation is also advantageous in industries where the temperature is very high and the humidity is low. These are the simplest and most economical methods available. If they fail to produce the desired improvement, resort must be had to refrigeration.

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DIE SCHÄDIGUNGEN DER HAUT DURCH BERUF UND GEWERBLICHE ARBEIT. Edited by *Karl Ullmann*, *Moriz Oppenheim*, and *J. H. Rille*. Paper. Volume II, Parts 9 to 12 (conclusion), pp. 385–567 with illustrations, and colored plates, title pages, and contents. Leipzig: Leopold Voss, 1926.[1]

Trýb describes the pathologic conditions affecting workers of the milk industry. The etiology of these diseases is partly mechanical, partly infectious. Recently Arzt described a condition called *Tylositas symmetrica hallucis*, occurring among workers who milk the cow according to the Swiss method. The symmetrical lesions are located over the extensor surface of the middle phalanx of both thumbs. The explanation of the rarity of direct transplantation of tuberculosis from the cow to milk workers is that involvement of the skin of the cow by tuberculosis is preceded usually by extensive involvement of the milk glands and the flow of the milk ceases before the lesions appear on the skin surface.

While chronic glanders is very common among animals, occurring in 90 per cent. of all the cases, the disease almost always runs an acute course in man. The invasion of the specific bacteria occurs through the skin in the majority of cases, but the way of entrance may at times be through the gastro-intestinal canal. Chronic gastric or intestinal ulcers with regional lymph node involvement are not rare as a result of this infection.

Anthrax, according to Rebentisch, is primarily an occupational disease. Interesting graphic presentation is given of the efficacy of the early serum treatment. Absolute rest of the entire body and especially of the part involved, aside from the specific treatment, is very important. This principle is carried out so efficiently by the Chilean Indians, among whom the disease is common, that anthrax is not considered a serious condition.

Ravogli of Cincinnati writes on blastomycosis of the skin. This condition occurs among workers whose occupation brings them in contact with animals or with furs. There are instructive illustrations of the different clinical manifestations of blastomycosis. Valuable detailed account is given of the morphologic and cultural characteristics of the pathogenic fungi of the skin lesions. Blastomycosis of the skin and rarely of the viscera is observed occasionally among sugar beet workers, and it is of interest that the pathogenic fungi may be obtained in pure culture from the beets.

In the chapter on pellagra, Oppenheim emphasizes the obscurity of the etiologic factors of this disease.

Our knowledge of the general pathology of dermatitis venenata is still very meager according to Perutz of Vienna. We are just beginning to understand certain aspects of the mechanism of the disease.

[1] For review of previous sections see THIS JOUR., 1925, vol. 7, p. 43; 1926, vol. 8, pp. 288 and 364.

A detailed account is given by Broers of Holland of the morphologic and chemical mechanism by means of which different plants and animals produce skin injuries. There is an encyclopedic enumeration of various plant and animal toxins producing skin injuries.—*Soma Weiss.*

DIE SCHÄDIGUNGEN DER HAUT DURCH BERUF UND GEWERBLICHE ARBEIT. Edited by *Karl Ullmann, Moriz Oppenheim,* and *J. H. Rille.* Paper. Volume III, Parts 3 to 6 (conclusion), pp. 97–308 with illustrations and index, and colored plates, title pages, and contents. Leipzig: Leopold Voss, 1926.

Occupational and industrial injuries of the skin represent one of the most interesting and important chapters of industrial hygiene. Never before has this phase of skin pathology been discussed and presented more clearly and thoroughly than it has been within these three volumes.[1] The numerous illustrations and colored plates are good and clear. Because different chapters discuss various skin injuries induced by the same agent, and then again the same type of injury caused by different factors, there are certain repetitions in the work. Such repetitions are, however, almost unavoidable. It is, of course, regrettable that no more effort was made on the part of the writers to discuss the various lesions of the skin on a general physiologic basis. But, after all, the lack of this accomplishment is simply a demonstration of our present ignorance of the physiologic and pathologic behavior of the skin.

In the second half of Volume III, which completes this comprehensive work, Koelsch describes industrial diseases of the superficial mucous membranes and of the teeth. These injuries are common among metal and stone workers. Particles of different substances produce injuries of varying severity in the eye. Iron, glass, or stone particles precipitate relatively slight inflammatory reactions in the eye, while copper particles are apt to produce extensive and long-persisting inflammation. Electric shock may cause diffuse opacity of the cornea and of the lens. Chronic lesions over the buccal aspect of the mucous membranes occur quite frequently among glass blowers. These lesions may resemble syphilitic plaques. Conjunctivitis caused by heat heals slowly. "Molecular necrosis" of the teeth is very common among workers of the inorganic acid industry. The condition is caused by the decalcifying effect of acid vapors present in the atmosphere. This process destroys the teeth practically completely within two or three years. Phosphorus poisoning produces a generalized sclerotic periostitis; as result of this condition the bones become less resistant to injuries, and infections spread easily. The jaw is more frequently than any other bone the seat of such rapidly progressing osteomyelitis, simply because there is in the carious teeth which are commonly present a constantly open door for infections within this bone. Among the chemical derivatives of chromium, the alkalichromates and chromic acid are very important. Workers of this industry frequently develop conjunctivitis and ulcers over the mucous membranes of the external auditory meatus, of the nose, pharynx, and even of the tonsils.

[1] For review of previous sections see footnote p. 310.

Perforation of the nasal septum, occasionally associated with necrosis of the bony parts of the nose, is quite common among chromium workers. Over 75 per cent. of the workers in the industry employed for over one year show perforations of the nasal septum. Lesions caused by other heavy metals are described. The "molecular necrosis" of the teeth of workers with sugars is caused by the changing of the sugar which is constantly present over and between the teeth into organic acids by the microorganisms of the mouth. This necrosis is therefore an "acid necrosis" in its final analysis.

Hessberg describes the injuries to the eyes caused by industry and occupations. There are numerous instructive illustrations in this chapter.

Ullmann of Vienna writes an excellent chapter on the question of cancer of the skin as related to occupational injuries. He points out that this phase of pathology is an exceedingly important one from the point of view of the study of the etiology and mechanism of the development of cancer. Here we have an opportunity to observe lesions in the benign or in the precancerous state for a long time. As early as 1780 Percival Pott, by describing soot cancer as "chimney sweeps' cancer," brought out the connection between occupation and malignant tumors. However, there was no progress in our knowledge on this subject until almost a century later, when Volkmann in 1875 and Tillmanns in 1880, with their descriptions of cancerous tumors produced by occupations connected with paraffin and coal tar, gave new impetus to the field. Today we know of a number of external factors which may precipitate cancerous lesions of the skin; still, studies of the occupational statistics give little or no help in clarifying the relationship between occupation and cancer of the skin.

Very important, from both the theoretical and the practical points of view, is the problem whether or not a single trauma may result in subsequent carcinoma. The question has also important medicolegal aspects. That cancerous growths were repeatedly observed at the site of a definite acute injury of the skin, occasionally as soon as two or three months after the injury, cannot be doubted. Whether the injury caused the cancer, or whether it simply precipitated the growth over a "predisposed area," cannot be stated with certainty. Important, also, are the observations of cancerous growths originating from the scar tissue following a simple trauma. One must therefore conclude that, even in the face of the previously prevailing skepticism, definite relation between single traumatic injury of the skin and cancerous growth exists in some instances. There are, of course, numerous examples of chronic and repeated injuries causing carcinoma of the skin. Certain skin areas predispose to malignant growths caused by chronic irritations.

Aside from mechanical and chronic chemical irritation, chronic radiation of the skin by heat and light may precipitate cancer. A remarkable illustration of the chronic heat factor is kangri cancer. The kangri is a vessel, filled with red-hot wood coals, which is carried as a thermophore between the thighs of the peddlers of Kashmir. The chronic irritation of the skin by

heat produces first quite characteristic precancerous changes; later an epithelioma over the inner surface of the thigh or over the lower aspect of the abdomen. Whether, aside from the primary heat factor, secondary infections of the necrotic areas play an important rôle in the precipitation of this type of epithelioma cannot be stated with certainty, but Neve, who is an authority on this disease, denies the importance of infection. In 1910 he observed 3,182 tumors in the Mission Hospital of Kashmir, among which 1,720 were of malignant nature, and of these 1,189 were epitheliomas, and 963 of the epitheliomas were typical kangri cancers. This may serve as an excellent illustration of the rôle of chronic physicochemical factors in the precipitation of malignant growths of the skin.

A classical description, with illustrations, of other types of skin cancers is also given.

It is hoped that the completed three volumes will occupy their deserved place in the library of everyone sincerely interested in industrial hygiene and clinical pathology.—*Soma Weiss.*

CLINICS, HOSPITALS AND HEALTH CENTERS. By *Michael M. Davis*, Ph.D., in Collaboration with Other Staff Members of the Committee on Dispensary Development of the United Hospital Fund of New York. Cloth. Pp. xvi, 546 with bibliography and index. New York and London: Harper & Brothers Publishers, 1927.

This book is the result of many years of research by the author, who is recognized as an eminent authority on dispensaries. In it we have the mature conclusions of a careful observer, who has had rare opportunities and a wealth of material to draw from, as well as able co-workers to supplement him in special fields. The industrial physician who is determined to make his clinic highly effective will glean many fine points from this interesting book.

There are thirty-one chapters grouped into five sections. The first section traces the history of medical practice in hospital and clinic and outlines the principles of institutional practice.

The second section gives the scope of clinic service and the relationship of the clinic to public health and community health and social agencies. The growth of clinic service in the last twenty-five years is well indicated by the fact that in 1900 there were about 150 clinics, and in 1925 the number had reached 5,000. At the present time there are 1,800 hospitals with outpatient departments, 220 group clinics, and 500 industrial clinics. The reason for this rapid growth in the number of clinics is that clinics provide more effective and economical medical practice than can otherwise be obtained.

The question of so-called "dispensary abuse" is discussed and figures are given from eleven published studies which show that only about 2 per cent. of clinic patients are able to pay. In this connection an enlightening table of personal income in the United States in 1918 from the National Bureau of Economic Research, covering 37,569,060 individuals, shows that 86 per cent. of all persons in the United States had incomes less than $2,000, and only 2 per cent. had over $5,000. A list of average per capita earnings and total incomes by states may prove valuable.

The question naturally arises: Upon what facts or principles is the patients' ability to pay to be determined? One investigator raises the pertinent question as to what percentage of the average physician's patients are "bad pay."

The third section treats of management of patients. The methods here presented for control of a clinic in order to use the physicians' knowledge and skill and for obtaining the best results for the patients constitute perhaps the greatest contribution which this book makes to our knowledge. The appointment system budgets the time and removes the hurry and confusion common in many clinics. The various steps are analyzed and sytematically planned. In one study of a men's clinic it was found that treatment involved regulation of ordinary habits in 65 per cent. of the patients.

Section four has to do with general administration including building plans, personnel, records, statistics, evaluation of the work, cost accounting and financing. The increase in admission fees and in the number of pay clinics gives a trend worthy of note and thought. With this may well go the mounting cost of dispensary care.

Section five takes up special clinics and clinics for various purposes. Those for mental, dental, and venereal diseases and for surgical cases may be of special interest to the industrialist.

The book contains a well-selected bibliography and an index making its valuable material readily accessible.—*A. B. Emmons.*

BOOKS RECEIVED

Books received are acknowledged in this column, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers and as space permits.

THE STATE AS A PARTY LITIGANT. By *Robert Dorsey Watkins*, Ph.D. Johns Hopkins University Studies in Historical and Political Science, Series XLV, No. 1. Paper. Pp. 212 with index. Baltimore: The Johns Hopkins Press, 1927.

MEMÓRIAS DO INSTITUTO DE BUTANTAN. 1926. Volume III. Paper. Pp. 331 and 23 plates. Part 1. Sao Paulo: Caixa Postal, 65.

THIS BUSINESS OF OPERATIONS. By *James Radley*. Foreword by J. M. Withrow, M.D., Chief of Staff, Christ Hospital, Cincinnati. Cloth. Pp. 96. Cincinnati: The Digest Publishing Co., 1927.

THE POLARIMETER. A LECTURE ON THE THEORY AND PRACTICE OF POLARIMETRY. By *Vivian T. Saunders*, M.D., Fellow of the Physical Society of London. Cloth. Pp. 29 and index; illustrated. London: Adam Hilger, Ltd., 1927.